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Industry 4.0: Is Portugal ready to change?

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Abstract

The world stands on the threshold of the fourth industrial revolution, also known as Industry 4.0. Having started in Germany, it rapidly gained a lot of attention and, although there is still no agreed definition, it is expected to radically transform businesses by merging virtual and physical worlds. This thesis uses a grounded theory methodology to analyze the data obtained in 9 interviews with experts, with the aim of identifying the adoption rate of Industry 4.0 in Portugal and understanding what are the factors influencing it. Five recommendations are proposed to increase the adoption and lead Portugal into the fourth revolution direction.

Keywords: Industry 4.0; Fourth Industrial Revolution; Internet of Things; Cyber-Physical Systems

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1. Introduction

After three decades of manufacture decline, an important debate is taking place about the future of the industrial sector and its role as an important key driver of research, productivity, job creation and contribution to gross domestic product (GDP), (European Commission 2012).

In order to reduce the pace of decay, many EU countries are discussing programs and measures to strengthen their manufacturing scene, studying how the success of the German model can be replicated in their own economies. A brighter future for global manufacturing arises with the fusion of the virtual and physical world, recently referred to as Industry 4.0. This smart manufacturing shifts from a centralized to a decentralized production and control (BMWi 2013) and, with new technologies, high-tech communication and low-cost sensors, it creates new possibilities to collect, analyze and rapidly make decisions based on data. With this, industrial processes become more efficient and production can meet specific customer's requirements.

The fourth industrial revolution is rapidly transforming the entire manufacturing system, where competition comes from digital organizations and innovative startups. To leverage on the benefits of this new reality, companies need to put Industry 4.0 at the top of their agenda and start their digital journey, changing their organizational structure and investing in pilot projects.

Due to the limited research on Industry 4.0 in Portugal, this master thesis will, not only, give an overview of the current and future factors of Industry 4.0 adoption, but also evaluate the readiness of the Portuguese economy to fully implement it. The study intends to answer the following research questions: *What is the current level of adoption of Industry 4.0 in Portugal?* and *What are the factors influencing the adoption of Industry 4.0 in Portugal?*

2. Literature Review

The world has been constantly evolving, and has been shaped by several industrial revolutions triggered by the need for competitive advantage, which lead to new ways of manufacturing and an increase in productivity. The 1st industrial revolution (18th century) replaced the agricultural

structure of society to a manufacturing one, with the development of mechanical production possible with steam engines; The 2nd industrial revolution (19th century) made use of electrical power, mass production and the division of labor; The 3rd industrial revolution (1969) emerged through the digital automation of production with the use of electronics and IT infrastructure. Right now, the 4th industrial revolution, also known as Industry 4.0, is ongoing and brings an emphasis on integration over isolation, based on connected technologies, heterogeneous data and collaborative knowledge. This new revolution, on contrary to the others, is predicted rather than observed (Drath and Horch 2014).

2.1 Industry 4.0

The fourth industrial revolution was first introduced in Germany, in 2011, at the Hanover Trade Fair, as part of its high-tech strategy with the name *Industrie 4.0*, presenting the idea of an integrated industry. The term Industry 4.0 also defined as the "Industrial Internet of Things", "Smart factories" or "Digital Factory" (Geissbauer, Vedso and Schrauf 2016), represents a paradigm shift from "centralized" to "decentralized" smart manufacturing, production and control, focusing on the end-to-end digitalization of all physical assets. Industries 4.0 include horizontal integration of data flow between companies, suppliers and customers, as well as vertical integration within the organizations' frames - from development to final product, resulting in a system where all processes are fully integrated, and the information is shared in real time (Hozdić 2015). The communication is made via Internet and allows interaction between humans (C2C), humans and machines (C2M) and among machines (M2M).

If well implemented, the fourth industrial revolution can reduce production costs, shorten production cycle, create higher asset utilization and improve product and service quality (Geissbauer, Vedso and Schrauf 2016). Improving customer experience will be at the center of the value chain, where, with the use of data analysis, products will be customizable by customers - the mass customization era - and moving towards the creation of unique products.

Given all the concepts associated with the Industry 4.0 and all the diverging opinions among researchers, finding a unique and concise definition is quite difficult (Hofmann and Rüsch 2017). Therefore, since Industry 4.0 is a combination of digital technologies, currently reaching maturity and when working together integrate both physical and virtual worlds (Geissbauer, Vedsø and Schrauf 2017), to have a clearer view of the subject, the core technologies of Industry 4.0 will be presented and clarified.

2.2 Industry 4.0 key technologies

Internet of Things (IoT): A key enabling technology that allows the Industry to go from 3.0 to Industry 4.0 because it adds a layer of intelligence into the manufacturing process. This technology provides "senses" to objects, so they are able to communicate, learn and perform their job more accurately (Trappey et al. 2017). IoT configuration includes on one hand, sensors, actuators and tags, and on the other hand, information protocols, middleware, and information technology (IT) - driven services, such as artificial intelligence, cloud computing and big data analytics; which are connected via wired and wireless sensing (Dopico et al. 2016; Ehret and Wirtz 2017).

Cyber-Physical Systems (CPS): Based on the IoT and connecting physical and virtual worlds. According to Lee and Seshia (2017, 1), *"A Cyber-Physical System is an integration of computation with physical processes"*. Embedded computers monitor and control the physical procedures, producing feedback loops that affect computations and vice versa. The term "embedded system" has already been used over time, however the revolutionary transformation occurs due to the networking of the devices connected by the Internet of Things, which enables the CPS to respond according to the environment, adapting to unexpected conditions and system failures (Lee 2008). In the manufacturing context, this means that information related to the physical shop floor and the virtual computational space are highly synchronized, giving the production process more control, transparency and efficiency (Lee, Bagheri and Kao 2014).

Artificial Intelligence: Giving machines the capacity to learn and act based on gathered information. Systems can understand their environment and act accordingly, being essential for a predictive decision making (Dopico et al. 2016).

Big data: All connected devices, systems and people communicating through data exchange generate large volumes of information, collected at increasing velocities and of different variety. Considering this, "Big Data" is a phenomenon that can have a big impact on value creation, providing important insights about processes and customers. In the Industry 4.0 context, a Big Data Analytics architecture and technologies are required in order to collect, store, process and analyze the data to support decision making (Santos et al. 2017).

Cloud computing: Companies are now able to affordably store all existing data collected in the cloud - externally to the organization at a data center. The large amounts of data are now available in real time, online, and can be easily accessible and updated, enabling a predictive optimization of production (Santos et al. 2017; Roblek, Meško and Krapež 2016).

The implementation of Industry 4.0 with the adoption of the above technologies, aims to the creation of a Smart Factory, which monitors the state of all things and is able to automatically react to events by controlling them (Wang et al. 2016). In addition, Smart Products know their production history, their current and target state and can direct themselves through the production process by giving instructions to machines, which are performing the required tasks and conveyors that guarantee their transportation to the next manufacturing stage (Hermann, Pentek and Otto 2016).

The similar use of connectivity, Internet and sensors in both IoT and CPS definitions might hinder the understanding if they are or not the same thing. Looking into studies of different authors, it is possible to detect the entanglement. Some authors state that IoT and CPS are aliases (Gubbi et al. 2015), others do not refer to the term Cyber-Physical System, but use related terms to CPS components, such as sensor, actuator and tags (Farooq et al. 2015). Besides

that, most authors state that IoT and CPS are different and that CPS is based on the IoT infrastructure (Cheng et al. 2016; Dopico et al. 2016; Rajkumar et al. 2010). Therefore, concerning the purpose of this study, IoT is the infrastructure and the technology embedded in devices allowing data transfer, nevertheless, it does not include data analytics. On the other hand, CPS's are part of the connectivity infrastructure of IoT and include complex data analytics. A representation of Internet of Things' components can be seen below (Figure 1).

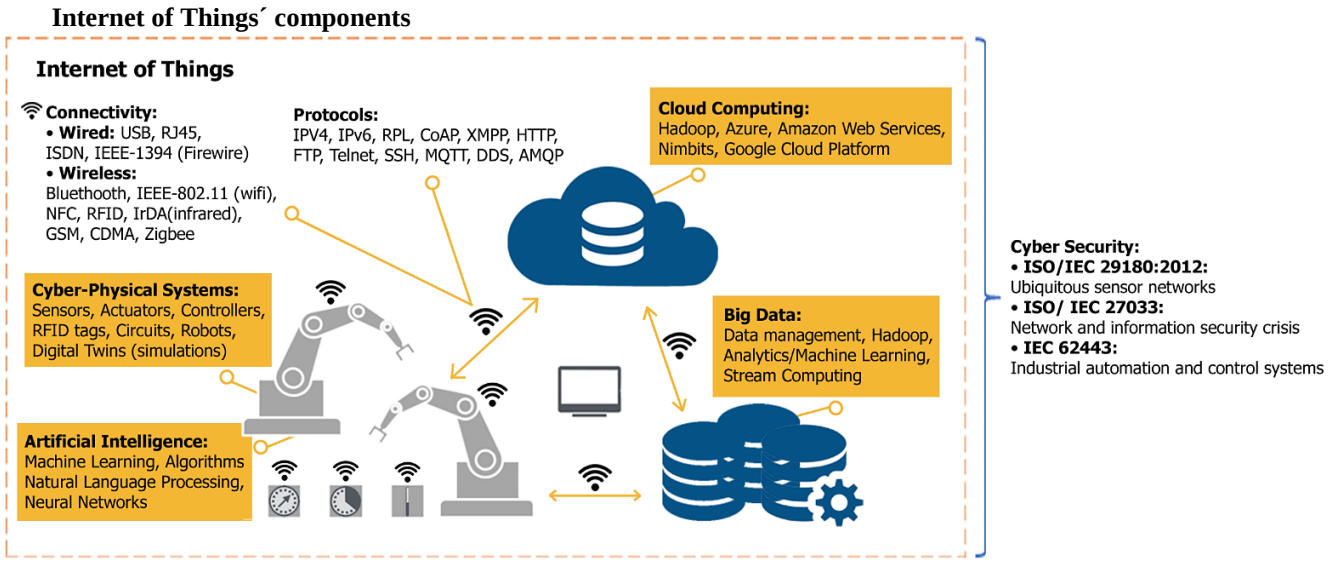


Figure 1. *Source: Original; Adapted from: (Trappey et al. 2017); (Gubbi et al. 2013); (Hofmann and Rüsch 2017)*

2.3 Factors influencing Industry 4.0 adoption

Although Industry 4.0 is becoming a more acknowledged topic, companies need to change and invest to adopt this new reality. According to the literature, a set of factors that influence Industry 4.0 adoption and implementation was identified and divided into six dimensions: Organizational, Technological, Economic, Political, Environmental and Legal.

From the organization point of view, there is still a lack of understanding of the topic Industry 4.0, its importance and the benefits it offers to the company (Erol, Schumacher and Sihn 2016). Moreover, some companies lack a strategic direction to implement it. However, most authors focus on not having the required know-how/having to learn new skills to be able to transform and the adaption of business models to a more flexible and continuously changing structure as the main constraints (Blanchet et al. 2014; Davies, Coole and Smith 2017; KPMG 2016;

McKinsey Digital 2015; Sniderman, Mahton and Cotteleer 2016). Regarding technological factors, not having a suitable existing IT-infrastructure and technologies, the necessity of having a standardized reference architecture and investing in data security systems are the main stated aspects (Hermann, Pentek and Otto 2016; KPMG 2016; McKinsey Digital 2015). Since high investment is needed, the economic factors focus on the financial requirements to invest in the necessary technologies and on the tax implications of Industry 4.0 (Erol, Schumacher and Sihn 2016; Pritchard et al. 2017). Political factors include public policies. The role of governmental policy is crucial for the growth of a manufacturing economy (Giffi et al. 2016). On environmental factors, it can be included the collaboration within the ecosystem. The critical success factor of Industry 4.0 will be the close collaboration between companies, especially SME's, IT vendors, system integrators, startups and universities (CGI 2017). Lastly, within the legal aspects, the key factors are legal requirements, mostly regarding privacy, data and intellectual property protection (KPMG 2016; Sniderman, Mahton and Cotteleer 2016).

2.4 Portugal overview: industrial sector, country's growth rate and startup scene

The Portuguese industrial sector is losing its power and a restructuring is necessary, enabling competitiveness and a positive impact in the country's economy. Currently, 99.9% of Portuguese companies are small and medium enterprises (SME's) and most do not have access to the whole supply chain because they do not produce finished goods (PORDATA 2017). The main sectors are: textiles, footwear, cork, paper and pulp, automobile and auto-parts, molds, ceramics and telecommunications. In 2016, the industrial sector accounted for 21.9% of the GDP and had 23.9% of labor force employment (Central Intelligence Agency 2017).

In the last decades, the Portuguese industry has suffered a transformation where some industrial sectors related to new technologies had a big development, such as automotive, electronics, energy and telecommunications (AICEP 2017). Nevertheless, the level of technological development of Portuguese industrial sectors is not homogeneous, where the traditional sector,

such as textiles and ceramics is still rather rudimental, with the use of few technological capabilities, on the other hand, the automotive and auto-part manufacturing already operates in high levels of automation.

With the economic crisis of 2007-2008 and 2010-2014, the expected Portuguese variation on the GDP of 2010-2020 is -0.5% compared to 1.2% of EU average. Despite this, the results obtained in the first and second trimester of 2017 are promising, reaching 2.8% and 3% growth respectively (INE 2017). Although there was a change in the Portuguese GDP, the levels of labor productivity have not had a significant variation, continuing very low. According to PORDATA (2017), Portugal has an average of 21.6 euros of productivity per hour worked in 2016, almost half of the European average, which is 39.2 euros.

Another constraint of the Portuguese economy is the education levels of its labor force. Portugal has an average education similar to countries like Brazil, Uruguay, Turkey and Philippines (Frederico, Veloso and Corraria 2017). Moreover, European countries that recently joined the European Union, such as Estonia, Czech Republic and Slovenia have higher education levels than Portugal (United Nations 2016). Another challenge regarding education is that half of the population still does not have the basic digital skills (European Commission 2017). However, if we only look at the population between the ages of 25-30 the results are considerably higher. Therefore, as new generations join the labor market and older retire, it is expected that these results will change quickly (Frederico, Veloso and Corraria 2017).

Regarding the Portuguese startup scene, although it still does not have a big impact on the economy, it is growing at a fast pace. According to SEP MONITOR (2015), in 2015, Portugal had 40 ICT Scaleups, meaning organizations that can create employment and innovation, and 9 Exits, which are companies acquired by larger ones. These are remarkable results especially considering the small size of the Portuguese economy. Moreover, many big industry players are also investing in Portugal by creating technological and research centers, for instance

Mercedes-Benz opened the world's first Digital Delivery Hub in Lisbon and, in 2016, it was one of the main sponsors of Web Summit, a tech-conference held in the capital. Another example is the close collaboration between Bosch and two Portuguese universities, Aveiro and Minho. These projects not only foster innovation and the creation of new jobs, but also allow the registration of patents. Bosch is a pioneer on Industry 4.0 and developed a R&D of new materials, quality control sensors and smart factory processes, in Braga.

3. Methodology

3.1 Data collection

For primary data collection, an applied qualitative approach in form of interviews was undertaken. As stated by King (1994, 14-15), "*the goal of this method is to see the research topic from the perspective of the interviewee"*. The research method was conducted in form of semi-structured, in-depth interviews, with an open-ended format, in order to obtain a larger set of results and be able to adapt the interview given a specific organizational context and in function of the conversation flow (Saunders, Lewis and Thornhill 2009).

Complementing that, this study used snowball sampling for data collection (Patton 2002). Using LinkedIn, an initial pool of interviewees was identified and those participants subsequently referred suitable new ones. For the selection criteria, the mandatory requisite was that contributors needed to be related with Industry 4.0 or similar fields. The main focus was on selecting people who had an understanding of the Portuguese environment. Nevertheless, and since Industry 4.0 originated in Germany, one interviewee has that nationality. The data collection took place between September and November of 2017 and counted with 9 contributors. Seven are Portuguese, one is German, and one is from the UK. All participants are male. The sample includes people working in academia, companies and startups, with different academic backgrounds. Table 1 gives a complete overview of the sample.

Table 1 *– Summary of Research Participants*

	Gender	Job	Country of Origin	Sample	Nº of people recomended
Expert 1	Male	CEO	Portugal	Initial Sample	1
Expert 2	Male	CEO/Consultant/Educator	UK	Initial Sample	--
Expert 3	Male	CEO	Portugal	Recommended	--
Expert 4	Male	CEO	Portugal	Recommended	2
Expert 5	Male	CTO	Germany	Recommended	--
Expert 6	Male	Professor/Director	Portugal	Initial Sample	1
Expert 7	Male	Professor	Portugal	Recommended	--
Expert 8	Male	Professor	Portugal	Recommended	--
Expert 9	Male	Engineer	Portugal	Initial Sample	2

In the beginning of each interview, the participants were introduced to the objectives and purpose of the research where any initial doubts were clarified. The interviewees were asked to define Industry 4.0, identify the main technologies, challenges for adoption in Portugal, and to give opinion on when, how and why it would be feasible for the country to fully implement it (Appendix A). The 9 interviews were conducted either face-to-face, via Skype or through email and had a duration of between thirty up to seventy minutes. The information gathered depended on whether the data saturation was achieved, meaning that no more new insights were obtained (Willig 2013). Furthermore, with the consent of the interlocutors, the interviews were audio-recorded, transcribed and translated near verbatim (Appendix B).

For this thesis, secondary data from books and online databases was also collected, selecting different articles published in recognized journals to assure more validity. The searched terms included "Industry 4.0", "Cyber-Physical Systems" and "Internet of Things". Due to the novelty of the subject in the country, there is limited adequate data available about Industry 4.0 in Portugal, therefore the data collected to create a solid knowledge about Industry 4.0 was complemented by the data obtained through the interviews to cross validate it.

3.2 Data analysis

Keeping in mind the objectives of the study, the raw data from the interviews was analyzed using a grounded theory approach. As stated by Willig (2013, 212), this method "*moves from data to theory so that new theories could emerge*". In order to understand events, grounded

theory methodology identifies categories of meaning by analyzing data from interviews (Saunders, Lewis and Thornhill 2009).

This process was developed using MAXQDA 12, a qualitative analysis software, which helped to organize and categorize the data collected. The interview scripts were analyzed and coded sentence-by-sentence and similar concepts were associated together, generating low-level categories (Willig 2013). Subsequently, the information was reviewed, and axial coding was conducted, where groups were again compared and combined in main categories. This stage allowed the development of a template of emerging factors (Strauss and Corbin 2008). Key findings include main components and technologies of the 4th industrial revolution and factors influencing Industry 4.0 adoption in Portugal, creating a theory that supports the research (Appendix C and D). According to Strauss and Corbin (2008), at the end of the analysis, selective coding must be performed. Though, this stage of obtaining core categories was not pursued, since for the goal of the study the concepts would become too abstract.

4. Results

4.1 Industry 4.0 according to experts

Through the conducted interviews it was noticeable that Industry 4.0 does not have a clear and agreed upon definition. Nevertheless, the topic is evolving and gaining attention due to the change in the consumption profile - consumers are demanding more personalized and unique products; and the revolution of technology – devices are becoming cheaper and increasing in computational capacity, reducing time to market and meeting customers' requirements.

All experts agree that Industry 4.0 is rapidly changing businesses and the manufacturing world, because it "takes the business world and the world of objects and connects everything together." (Expert 2). Thus, in the vertical view, Industry 4.0 integrates all processes of the company from the factory floor to the management systems, "factory floor systems can directly receive manufacturing orders from a management system and coordinate all production" (Expert 7),

allowing the factory to autonomously organize itself because smart products can interact with machines and perform the necessary transformations. The horizontal integration part is between the various participants of the production chain, from suppliers to end customers. There is a shift from being reactive to preventive, because a full vision of the factory is available that allows to detect problems as soon as they happen, predict them and make quicker decisions. Right now, the most important strategic asset of a business is not knowledge, but data, "the new currency is data" (Expert 2). This brings companies a huge advantage of higher efficiency and a significant drop in costs, one expert estimates "about 70 to 80% cost reduction" (Expert 3). The 4th industrial revolution is only possible due to the growth of technologies, such as artificial intelligence to be able to predict, cyber-physical systems, clouds to have centralized information, Internet of Things because it enables the connectivity between all participants and, on top of everything, a strong cyber security network. When talking about CPS, another concept has emerged - the digital twin -, which is a digital replica of the production system that allows "a digital mapping of everything that happens in the physical environment" (Expert 4).

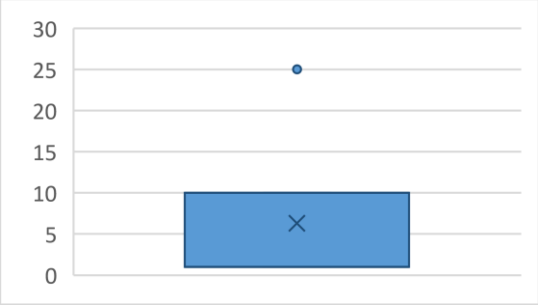
When questioned about the confusion between IoT and CPS, most of the interviewees agreed that CPS's were integrated in the IoT connectivity network. CPS is a sensor, for example, that captures information from the physical world and sends it to the cloud, the artificial intelligence then analyses it and makes the decision, and this is only possible because of IoT. Overall, experts believe that Industry 4.0 will change the way the world operates, "It is impossible not to have a holistic view of Industry 4.0 otherwise we would not understand the phenomenon, but it generates an impact that is overwhelming and perhaps, for that reason, it is considered an industrial revolution, because in fact the transformation is extremely big." (Expert 6).

4.2 Current level of adoption of Industry 4.0 in Portugal

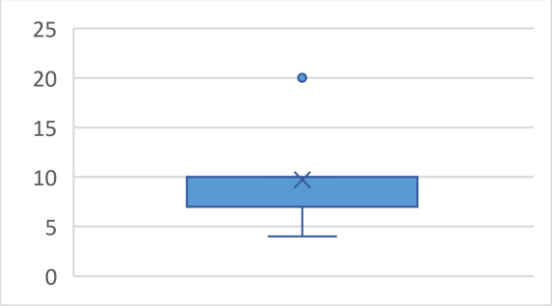
All experts agree that the level of adoption of Industry 4.0 in Portugal is quite low. Some interviewees believe that the country is not prepared for the adoption and cannot give a precise

number. Others state that Portugal has only 1% of adoption, while some suggest that it is at 10% or less. Lastly, one of the experts thinks the country is at 25% of adoption.

When asked to estimate the number of years that will take Portugal to have a fully implemented Industry 4.0, experts had different opinions. One of them thinks that the evolution of this trend will have a gigantic growth in the next few years and that is crucial for Portugal to create the necessary mechanisms to adopt until 2021, with risk of losing the train and entering a new economic crisis. Another interviewee tried to balance his optimism of new generations entering the labor market and pessimism of a stagnant economy, stating that the country will always be behind, and the crucial aspect is to reduce the gap. He believes Portugal will still need more than 10 years for Industry 4.0 to be the standard, but in between 5 to 8 years a lot of businesses will have adopted to some extent. 20 years is another estimation, once again because Portugal is lagging and has a very heterogeneous and unbalanced business environment. (Graph 1 and 2)



Graph 1. Current level of adoption of Industry 4.0 In Portugal (%)



Graph 2. Nº of years it will take Portugal to have a fully implemented Industry 4.0

4.3 Factors influencing the Portuguese Industry 4.0 adoption

An overview of the analyzed data is summarized in Appendix D, where the first order concepts and key themes of the thesis are presented. Hence, the key themes that emerged from the study are Organizational, Societal, Governmental, Portuguese Business Environment and Portuguese Industrial Scene, which represent the main factors influencing Industry 4.0 adoption.

Organizational

Regarding company specific factors, the main one identified by the experts was the lack of understanding and acceptance that decision makers have of the phenomenon which most of the

time hinders the investment in technology that, in the long run, could bring advantages, "if you have a similar investment in software, that will allow them to achieve a productivity level equal or greater than they can with a new machine, they do not do it" (Expert 4). Another important factor is the lack of skilled personnel and, once again, the investment needed to train and requalify employees "training programs have to be more ambitious, (…) and have to qualify their workers for a professional progression that is done towards the up-skilling and re-skilling." (Expert 6). However, employees should have a different approach towards knowledge, having a more proactive attitude and making use of the knowledge offered inside and outside the firm.

Societal

The main factor referred by most experts is regarding mentality. Participants do not believe Portuguese society is ready for Industry 4.0, there is fear of automation and job loss, which is related with misinformation and misunderstanding. Moreover, there is a stagnant society and economy that does not want to invest in things that bring risk. One expert believes that it is needed "a change of attitude to a more entrepreneurial attitude" (Expert 6), and entrepreneurial in terms of being proactive, not waiting for things to be solved alone and not being risk averse. Another societal factor is the high emigration values, especially of younger generations with digital skills, "Portugal is losing young people all the time, so it needs to be a reason to bring them back and for the first time in human history we can do business on mobiles" (Expert 2).

Governmental

Portugal's economic growth and development is very dependent on governmental decisions. The creation of public policies that help businesses and fosters a creative business environment is crucial, "As Portugal is a small country, we need to focus on public policies (…) if the government does not want to do things, they do not happen.", the interviewee adds "Look at Industry 3.0, the automotive sector, it only happened because AutoEuropa settled here (…) In fact, it was a public policy in the 90s that brought all this." (Expert 3). There are also regulatory

and legislative constraints, such as labor regulation. Expert 6 states that the country is not prepared to promote labor flexibility, for example inter-firms mobility, collaborative and remote work, among other realities that arise with innovation, "The Portuguese labor legislation (…) I would say it is not adjusted to the current reality, much less the reality that 4.0 will generalize". Moreover, another expert believes that the Portuguese tax system also has its flaws and "is made for the 20th century", he adds that "The only way to keep people in Portugal, working at factories is to reduce the social security tax to 0." (Expert 1).

Portuguese business environment

The Portuguese business environment is mainly constituted of small and medium companies that have a lot of obstacles to surpass, such as "lack of scale effect, (…) lack of capital, lack of capacity to withstand the investment in qualified human resources" (Expert 6). These enterprises have greater difficulty to invest in change and innovation programs and to understand the great impact that Industry 4.0 could bring them in the long run. In countries like Germany where there is a very structured and strong industrial base with big players, large implementation projects are led by these actors and followed by smaller companies. Since in Portugal most companies are SME's, this is harder to accomplish because they "have little investment capacity and less capacity to invest in large-scale programs." (Expert 7). Moreover, Portugal is "late coming to the digital" (Expert 2) and although this creates several problems, such as lack of self-confidence and the creation of a close-minded society with low digital skills, mainly due to the lack of previous experience in dealing with these matters, it can also bring some advantages because "there is no legacy investments" (Expert 2). It is necessary a more proactive business environment to increase the pace of adoption, nevertheless this "is something structural in our country" (Expert 6) and experts do not know how it will be surpassed.

A positive factor is the growing Startup scene. These new companies have competitive advantage by creating new solutions since they are more agile and can respond rapidly to

environmental changes. In addition, the idea of collaboration between companies emerges, "if you connect the startups that make the platforms with the companies that own the machines (…) you allow them to move up the value chain" (Expert 3).

Portuguese industrial scene

Portugal is not a country with a strong industrial tradition, nevertheless there are some sectors where Portuguese companies have been growing and investing a lot, such as molds and footwear, but overall the country has a very heterogenous industrial base where there are still many traditional sectors. Not having a strong industrial scene weakens the support given to employment, which is lower than in other countries. This situation got worse when there was the reallocation of production to Asian countries to reduce costs, and "what happens is that we lose the skills and we lose more than the skills, we lose the habit of dealing and surviving in a difficult environment.", as referred by Expert 1. In addition, and as cited by Expert 3, "Portugal is not a country of end-product industry - is a country of pieces". This means that since a lot of companies only manufacture a specific part of a product and then supply it to Germany, for instance, Portuguese organizations are dependent on what bigger companies decide because they do not have a brand or any control of the value chain and cannot define margins.

5. Discussion

Although this topic is being more discussed and various governmental programs are being created all around the world, there is still a gap in the literature regarding the main factors influencing the adoption, especially when we take the Portuguese example into account. The factors were grouped in key themes giving an overview of which areas are impacting the Industry 4.0 adoption in the country and, although some results of the study are in accordance with previous studies, this thesis brings new insights about the Portuguese reality.

Erol, Schumacher and Sihn (2016) refer the lack of understanding of the phenomenon, financial difficulties in investing in appropriate technology and defining a strategic direction as some of

the problems that companies have to deal with. These factors were also identified in the experts' interviews, where the lack of perception and the need of investment were mentioned several times. These two factors have an even greater impact in the Portuguese context, since the country is mostly constituted of SME's, that have access to less resources and most do not have the initiative of adopting new technologies, just following the big players of the ecosystem.

Another aspect present in the literature review is the need of a qualified workforce able to learn and adapt (Blanchet et al. 2014; Davies, Coole and Smith 2017). The interviewees of the present study also mentioned that employees need to be proactive, continuously learn and search for new knowledge. In addition, they also stated that the (re)training of the workforce must be adapted to this new paradigm and that education establishments have to start preparing the current and future generations with digital skills. It is noteworthy that the necessity of changing business models was not voluntary cited as a key factor, although it is referred in other papers.

A lot of studies focused on the importance of technology development factors. According to Hozdić (2015), this is the most significant prerequisite in successfully implementing Industry 4.0. Moreover, CGI (2017) also mentions the required modernization and investment in existing unconnected devices and systems. Nevertheless, in the conducted interviews this factor was referred more as a need of investment, but not considered the most crucial for Portugal.

Giffi et al. (2016) further proposed that the government role and public policies are extremelly important for the development of the economy. This was also verified in the present study, as participants refered the governement as the catalist of growth and innovation. Public policies should promote, support and educate businesses for the transformation process, more so than just providing direct funding. Moreover, the State can also create regulatory systems which facilitate tax measures, encourage research and development and promote work flexibility. The legal requirements that emerged from the qualitative research were different from the ones

mainly existent in other researches, that have a stronger emphasis on privacy, data and intellectual property protection (Sniderman, Mahton, and Cotteleer 2016).

The important growth of the Portuguese Startup scene was also discussed in the interviews and was also found in several studies, (CGI 2017; Hoffmann and Prause 2016). The idea of having a collaborative ecossystem with the integration of SME's and Startups is crucial for knowledge sharing and idea creation, and is an opportunity for businesses to create their own brand.

There were other key schemes that arose from the interviews, such as Societal, Portuguese business environment and Portuguese industrial scene, which, although some sub factors included in these are found in other studies and mentioned above, most of these issues are very country specific and more difficult to generalize, nevertheless they can serve as a starting point when studying other countries and as a way to identify either similarities or differences.

From the results it is noticeable that there are many factors influencing the Portuguese Industry 4.0 adoption, being the most referred ones, a) the high investment needed, b) the power of the government in the economy and c) the lack of knowledge and information of what Industry 4.0 encompasses. Therefore, these can justify the low adoption rates of Portuguese businesses, which according to the experts is non-existent or very low.

5.1 Practical Implications

It is clear that Industry 4.0 can have a great impact on a country, generating growth and productivity gains (Rose et al. 2016). Nevertheless, Portugal needs a significant transformation on the structural basis of economy, especially when productivity levels are considered, since they are still recovering from the low investment during the crisis. It is crucial to finance and develop technology and innovation, which are some of the factors that can increase productivity, along with a better qualification of workers and work organization, as stated by Eurostat (INE 2013). From the collected insights and in order to facilitate the comprehension and implementation of the topic, this study proposes five recommendations:

Funding: Although it should not be the only thing done by the government, the creation of subsidies and other funding mechanisms should exist. Nevertheless, it should be a more strict and controlled process with a set of objectives to accomplish in order to be a suitable candidate.

Education: The education system and business environment must change and adapt, since the work setting and skill set needed is changing. According to Directorate General For Internal Policies (2016), a higher demand for positions requiring problem-solving, analytic skills and proactivity will be needed and studies suggest that the skilled labor force to support Industry 4.0 still does not exist. The role of government is important to support and prepare citizens for the transformation by gradually adapting the education curricula, working together with schools and universities and reorganizing the education system.

Knowledge and technological center: The decentralization of technology, the rise of innovations and knowledge sharing can radically change businesses and be an innovative solution for SME's (Bridgers 2017). The creation of technology centers with trust systems based on blockchain was also mention in the interviews and requires less investment from companies. It could work as a technology distribution center and even as a "work search platform". The organizations and independent employees could connect to the wire and it would feed and update business needs. This could be created as a Consortium Blockchain, requiring some prerequisites to the able to participate. Moreover, a private institution should be in charge of setting up the network and guaranteeing its operability. The power should be distributed among all stakeholders and any change demands everyone's agreement. The advantages of this system would be the transparency, the straightforward contact with other big companies who are also part of the network and the easiness of access by firms who could acquire the technology and skills needed in small manageable steps with almost no investment.

Awareness: It is important to create awareness about the topic, so that the lack of understanding of businesses is mitigated. A shared partnership between the government, universities and

businesses should exist to invest in several programs, such as the creation of model smart factories, visits to these factories to comprehend how they work, promotion of companies that offer solutions in these areas and specific courses for universities and for business training.

Collaborative ecosystem: The country should take successful past experiences into account, such as the footwear, textiles and wine sectors, which were struggling to remain competitive and survived because they joined forces with universities. Moreover, the Portuguese startup scene is growing but it is still mainly focused in Lisbon. It would be important to invest in other Portuguese cities that have potential and resources. In addition, the physical connection to other European cities is also missing. Lastly, and as previous mentioned, the collaboration between startups and SME's can also increase the Portuguese productivity by enabling companies to create their own brand and control their margins, this requires a proactive attitude from Portuguese businesses. Once again, the government should have an active role by promoting decentralization of institutions and ensuring an efficient physical connectivity with Europe.

5.2 Limitations and further research

Regarding the representativeness of the sample, due to the need to interview Industry 4.0 experts, mainly operating in Portugal, there was some difficulty in finding available participants. Moreover, the time-consuming nature of the qualitative data collection and analysis was also an inhibitor of having a larger sample. Nevertheless, and according to Willig (2013, 94) "*even though we do not know who or how many people share a particular experience, once we have identified it through qualitative research, we do know that it is available within a culture or society*", so, in this particular case, we can potentially generalize the data gathered. Furthermore, the topic Industry 4.0 in the Portuguese context is still not very explored, therefore there is a reduced quantity of academic resources to compare results.

Due to the vast amount of information about Industry 4.0 and the numerous possibilities of areas to develop a study on, there was a need to shorten the scope of the research, which

originally had three research questions. Since this was not possible in this study, it is a great opportunity for future research to use this paper as a starting point to further explore the topic, by understanding how policy makers can influence the adoption rates of Industry 4.0 in the country. Moreover, a survey can be sent to a sample of Portuguese companies to measure their adoption level of Industry 4.0, giving a greater validity to the obtained results. Other interesting topics to develop would be identifying different company partnerships that can foster innovation or focusing on change management mechanisms which are also going to be needed to help companies embrace this new reality.

6. Conclusion

Through the conducted master thesis, it was possible to further explore and clarify the topic of Industry 4.0 and assess the level of adoption in Portugal. Using the grounded theory approach the main factors influencing the rate of adoption were identified, being the investment needed, lack of understanding and acceptance of the phenomenon and the impact of governmental decisions. It is clear that the government has a decisive role as the main promoter and facilitator of initiatives and regulations. Industry 4.0 can have a great positive impact in the Portuguese society, however, it is important to have a collaborative ecosystem ready to educate and prepare the population. The aim of this study is to create awareness to the 4th industrial revolution and that the main recommendations can lead businesses to start taking part in this transformation. Portugal needs to move quickly and make sure it enters the train in the next station, because Industry 4.0 is happening now and is not going to stop.

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A Work Project, presented as part of the requirements for the Award of a Master Degree in Management from the NOVA – School of Business and Economics

Industry 4.0: Is Portugal ready to change?

Appendices

❖

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A Project carried out on the Master in Management Program, under the supervision of

Leid Zejnilović

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Q4. What are the biggest challenges for companies to transition to Industry 4.0 in Portugal (Investment, Employment and skills development, need to change business models, Data ownership and security, Legal issues, others)? *Why do you think so?*

Q5. Which companies/industry sectors are the most affected by Industry 4.0? (Is one more affected than the others?)

Q6. Where is your company in the Industry 4.0 ecosystem? (is it an enabler, provider of solutions, user, connector…)

Q7. How is your organization implementing Industry 4.0 initiatives?

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Q9. Is the production data shared within the ecosystem (along the supply chain), i.e. inter-company?

Q10. What financial mechanisms is your company using to obtain investment for Industry 4.0 components?

Q11. What do you think will be the main impacts of not adopting Industry 4.0 technologies?

Q12. What could be the "new" role for the remaining human resources in Smart Factories? What skills will they need?

Q13. What is the level of the adoption of Industry 4.0 in Portugal, in percentage from 0 to 100?

Q14. If you had to estimate, how many years do you think it will take Portugal to have fully adopted Industry 4.0? (meaning most companies have integrated Industry 4.0 technologies)

Q15. Can you recommend 5 other specialists in the field with whom I should get in contact?

Appendix B – Interview transcripts

Expert 1 Interview

Job Title: CEO

Interview date: 20th of September of 2017

Interview local: Non- applicable – Skype Interview

Interview length: Thirty minutes

Good afternoon. First of all, thank you for your availability to share with me some information. I am doing my thesis on Industry 4.0 in Portugal and I would like to know your view on this topic in order to understand your perception and analyze the level of adoption of the Portuguese industrial sector. Therefore, I have a set of questions I would like to ask you.

I start by asking you what is Industry 4.0?

- Yes, that is a good question, because it is what I understand, this is a subject that is not very limited and if we listen to 10 people, we would probably hear 10 completely different opinions. Well, what I understand by Industry 4.0 is a sequence of what has been a shortening of product lifecycles and, when changes are only made at the software level things are relatively fast, but, when we talk about industrial terms and by the nature of what is now the industry, each company knows very little about a lot of things and making a product involves many different things, therefore it involves a wide range of companies, entities, people and each one knows a lot about what it does, but knows little about what others do. And how can you, on the one hand, make less mistakes and try to get more into the features that can be marketable to

customers, which are the characteristics of the product, in order to achieve the desires of the consumer, which some do not even know they have. And this need, on the one hand, to reduce failure in the characteristics of the product, and on the other, to reduce everything that can consume time and money in response to the market, which is very short nowadays. Today the link between the industrial part and the marketing and the promotion and the distribution, everything is now connected, where in the past they were segmented areas.

Therefore, Industry 4.0 brings data and brings information and electronic and digital systems that allow, on the one hand, to absorb the conception part of the product, and on the other hand, during the production stage, to help manage the production with all these participants in a harmonious way. So, what I think that Industry 4.0 is, is the transformation of information in increasing speed and cost reduction in order to be able to produce and market a product.

You mention some challenges, but what are the main challenges when a company wants to transition to Industry 4.0?

- If we are talking about Portugal, they are huge. What kills my company is precisely the fact that there is no industrial tradition, the only industrial tradition that we have is footwear and textiles, all traditional sectors and there is no industrial tradition in these startups sectors and everything. And investors work based on past experiences, when somebody comes up with a new idea, they don't want it, they want someone to come up with a new idea, but that is similar to all the others. Therefore, first challenge, the mentality and this mentality comes from experience.

When, in the past, we started to think that we should only produce cheap and therefore we relocated the production to China, to Vietnam, to Thailand, what happens is that we lose the skills and we lose more than the skills, we lose the habit of dealing and surviving in a difficult environment.

It is a bit like Darwin's law, we suffer a mutation, and we need to change to adapt to the new environment, if the environment changes again we are, again, not adapted to it, and this intangible characteristic is crucial in this. And this is happening in industry, if we have no industrial capacity, we have no skills or self-confidence. And for the skills I can create a course and train new people, but I can't do that with the self-confidence because it comes a lot from experience. So, I do not believe that it is now possible to do industry in a more wide-ranging way than exists today in this geography, because of these two characteristics.

It takes investment, the investor since has not dealt with this for many years, has lost the feeling, for them anything new means risk and he does not want risk, so this is the biggest difficulty there is. And then they just want to invest in phases when companies are already with high degrees of maturity. What happens is, if you do not invest in startups in early stages, you never feed the chain again.

Moreover, everything in Portugal is connected to the government and we have to work with less money.

Speaking about technology, what do you consider the most important technologies for this new industry?

- For me, electronics is inevitable, more so than software, which I feel bad, because it will reduce jobs, but the solution is robots, and that implies automation, implies electronics, the software is inherent, because if I have sensors and electronics systems I have to have software, but for me, this is the determinant part and everything else is linked to this, so augmented reality, virtual reality, this in the production part.

In the other parts of the industry, the software has a great opportunity, because if at the design stage I can get right what the customer wants, I can produce it quickly and retain the client, but for that, I have to have people who know a lot about communication, digital marketing, people who write very well.

These two hardware and software components are very important.

So, you believe that in the future we can have a totally autonomous factory, without any employees?

- I believe so. Of course, it depends on the products and the dimension and sector, for example in microelectronics is very difficult, because it was only possible with expensive machines and that is not worth it.

We continue with a tax organization made for the 20th century. The only way to keep people in Portugal, working at factories is to reduce the social security tax to 0.

But the employees that continue to work, will have to change their skills, what skills do you think they will need?

- I think, those who can manage better people will win. There will be less people, but they are important, all this people/suppliers/customers management. Leadership as well, this is what can still save some human beings from being completely useless. Social skills are necessary, because the machines still do not socialize, they still do not convince anyone, so it is very important to understand what this social management means.

Do you think that industry 4.0 will require the collaboration of several players, larger companies, startups, universities, that it is important that they are all linked or do you not consider it important for implementation?

- Once again it depends on the sector and the business, but I think so. There are two good cases in Portugal, footwear and textiles, which a few years ago were the failed industries and then the best ones survived because they connected with universities. Also, the wine sector, which joined universities and grew a lot. Those who are able to collect this knowledge are more likely to win.

Once again, thank you for your time and valuable insights.

Expert 2 Interview

Job Functions: CEO, Consultant, Educator

Interview date: 21st of September of 2017

Interview local: Non- applicable – Skype Interview

Interview length: One hour and ten minutes

Good afternoon. First of all, thank you for your availability to share with me some information. I am doing my thesis on Industry 4.0 in Portugal and I would like to know your view on this topic in order to understand your perception and analyze the level of adoption of the Portuguese industrial sector. Therefore, I have a set of questions I would like to ask you.

What is Industry 4.0?

- That's a very good question, there are many different definitions of Industry 4.0, to me, before defining it, I would like to define digital business, because to some people digital business is just empty, it's just we are a digital business because we have enabled technology in our process. To have a traditional IT department in a company, that is not digital business, digital business is about the transformation of the business ecosystem, on B2B, B2C basis to one up completely integrated technological focus and process across the whole spectrum of the business activities. So, technology is not an enabler, technology is business. So, business has now become technology, it is not a department that sits on a corporation. So, the internet has enabled social platforms, and all the engagement with a customer, whether that customer is another business or a consumer, via technology. So, an ecosystem of businesses has changed from groups of people conducting transactions across a market to a global ecosystem completely connected in every dimension. So, business itself has completely transformed and I think it is important to be very clear on that, because still many executives I talk to at the C

level think that digital business is all the fancy technology, but that is not digital business that is just doing business as normal. Industry 4.0 is transforming digital business, so we have in my view 3 steps: IT comes out of its little box and IT now becomes business and now business most become interconnected to be successful, because we no longer have walls in business, because you and I and everybody on this planet has the ability to connect to each other. That is the first step and that is a significant paradigm change many executives still do not understand and many commentators fail to see, this has a size make shift in understanding business. Industry 4.0 now takes the business world and the world of objects, non-tangible objects and connects everything together, not just business, we have everything. So, every device on the planet has the capability to talk to every other device and to talk to every person, so now we move from the reality of IT in a box. Business must be conducted on a personal level of relations across a transactional marketplace, that marketplace has gone from being local to global and it started with technology on the back room, so we connected our processes because we developed our supply chain, etc., etc. and what we get ultimately is a position where the most important strategic asset for business is not necessarily knowledge, because all the knowledge in the world is available for free, we have google, ask google. So, it is not knowledge, it is data, so the new currency it's data. So, we have structured change, we have mindset change and now we have a whole new way of valuing business and conducting business and this is about data. So, he who controls the data has the power. So, from the current climate we have two possibilities, Google and Facebook control the majority of data in the world, from a system perspective these are two regulators, they control the flow of data, through two connection points, which allows you to connect to everybody else. It is monopolistic, yes, they have pretty much the monopoly on the data, which they sell to other business, so the strategic currency is now data. So we are moving into a world of Big Data and there's a huge big thing called Industry 4.0 that is sitting there and if you ask some people what Industry 4.0 is, you probably get 10 people looking at you saying

"what are you talking about?" and then there is one person who will say "oh is that something to do with the internet of things?", so we don't know, I don't think that there is a really clear, agreed upon, definition about what Industry 4.0 is. Europe has a definition, USA has another, UK has a definition… I think the question is "what can and will Industry 4.0 do to businesses and existing business structures", it will completely destroy them, it will change the way the world operates.

That is why it is the fourth industrial revolution right?

- Yeah, I would say probably the fifth, we had a few little mini revolutions. I'm not even sure if I like Industry 4.0 has a way of describing it, it is easy if I say Industry 4.0 for other people to understand me, but really is not Industry 4.0, it is society 4.0, it is world 4.0. It is the transformation of everything that we do, everything we though we knew, can now be conducted in a completely different way. So, we have automation, artificial intelligence, machine learning, big data, all of these things will have an impact on the world of business. I know it's not really a definition, but I want to paint a picture of the issue. And this is where we get confused between Industry 4.0 and digital business, and I firmly believe digital business is an umbrella. Digital business is about conducting business in a different way, with both enabling and transformation technologies. And what happens in a world of automation? I deal with this every day, this is only one piece of a huge transformation. For me, I think the problem is on mentality, for most businesses the problem is in perception, is on understanding and acceptance. And I don't think businesses are necessarily ready, I think big businesses which have more power and funding, disposable income, can assign money to enabling technologies quickly, but the biggest threat to digital business right now, is the government, that is a huge threat to government, it is a huge threat to the structure of society and how do we implement this in Portugal? But how do we enable a digital transformation in the Portuguese economy? So, that is a good question.

So, do you work with Portuguese companies in your organization?

- No, international, I don't work with Portuguese companies, my clients in the last 10 to 20 years as a consultant and as an educator on a doctoral program in business and technology, my clients, unfortunately, are not Portuguese, I wish they were. So, I don't work with Portuguese companies at the moment, but I would like to. Lisbon has a very active technology scene at the moment, lots of startups, lots of business change but it still hasn't broken out of the Iberian Peninsula. I think the next stage is how do we take this innovation and creativity that is taken place in Lisbon and how do we get it out of Lisbon into the world. How do we work with businesses to force them to make structural change of their businesses and then bring it to the world. We need to focus on the SME's, for instance I am in Algarve, it is a touristic area but during the winter nothing happens, so where is the technology? There is opportunity for businesses and I think this happens in all Portugal, when you move outside of Lisbon and Oporto, there is nothing. I think there is a great opportunity because Portugal and Portuguese businesses and I say this with the greatest respect, but Portuguese business is late coming to the digital, but this is a huge advantage because now we don't have legacy investments, when my company talk with companies the first problem that we have is the Chief financial officer, that goes "we have invested so much in the new technology and you are telling me we have to trough it all out?", so this is the very first wall that we meet, the CFO and he says "no, no, no, no…too much money has been spent", so this is why we have to change the mindset. But here in Portugal, there is not a lot of legacy investment in IT, so this is pretty much still a personal thing, who you know, the relationships and the government, because the government has its finger in everybody, so by changing this I think there is a huge opportunity for Portugal to take a lead economical in Europe, and there is a quote from Europe, that funds, so that is what I think is the future for Portugal.

You were also talking about that businesses have to adapt, so they probably have to change their business model? So what characteristics would you consider most critical for a new business model?

- A business model has to be viable, so to be viable it means it has to have the agile structures that continuously change. Business models are typically fixed, although there are conceptual, they are intangible, but it is about the culture. The culture of a company is the glue that keeps the organization connecting. The way of doing business has changed dramatically so, therefore the business model of right now it's a viable system model, so to be viable it means it needs to be able to adapt and to adopt to changes as they happen in real time and this is problematic, believe me, I know. We need an elastic business model, something that can stretch in every direction, so it is not fixed, what I call a viable system, which is a cybernetic system that is able to look at both external and internal and adjust connecting into its dynamics of the market, its people, its structure, knowledge, data… it can change. Now, because the velocity of change is constantly increasing and existing practices, existing methods are not able to keep up with this level of change. So, they are thinking like Industry 2.0, but the world is Industry 4.0, so we have a huge disconnect and this is the problem.

So, you were talking about the SME's and a huge problem is the investment, so how can these companies actually get funding to invest in new technologies?

- I will answer this question of what I see is a vision of the future for SME's, you are correct, let's break it down into two different pieces. The first piece is the investors, the financial aspect, the second piece is the time, time and knowledge. So, for investment, SME's will never have access to the level of investment that is required to be possible to change. So, if we take the financial investment piece and put it into one side, now let's look at time and knowledge. If I'm an SME company, where do I invest my time? I invest my time in trying to manage my business, that is the first, and if I take my time away from managing my business, my business

collapses. What do I need to help me to manage my business, I need to change, I need to be able to change, so SME's do not have legacy investments because they can't afford to put in big, expensive IT systems, but what we are seeing now with digital business is the decentralization of technology, and we haven't even touched on blockchain yet, because that is another element that is coming, is here right now, and is changing everything we know about businesses, no more lawyers, no more CFO's, we don't need them, very fast, lean integrated supply chain, with trust systems based on block chain, so it is the perfect solution for SME's because they don't have to invest. So, my opinion, and I love SME's I think they are the champions of every economy, but they are being ignore because we have the big companies, and everybody wants to work with big companies, so with SME is time and knowledge, to spend the time in trying to understand what they have to do to make the change, because the change is happening so fast. So, let's look at the German example, very fixed supply chains based over generations, doing the same thing over the years, nothing has changed, how does a Portuguese SME grow into this market, very difficult. So, we take finance out, time out, you cannot expect an SME company to be on top of knowledge all the time, it is impossible it changes too quickly and you cannot also expect them to invest the time necessary to understand the knowledge, because they have to focus on their business, so what I see happening for SME's is: we will have the creation of software cooperatives, where a community comes together as a coop and invest together in technology to succeed. And I believe that we will see distributor centers, so the opportunity is in the establishment of distribution technology centers and can be on any location in the planet that SME's can literally plug into and this software center continuously updates and feeds the mechanisms of the SME and manages their business in Industry 4.0. So with blockchain, which is a trust system, we don't need lawyers, we don't need accountants, we don't need quality control, because we have the rules that exist all the way through the chain and by creating a decentralized blockchain for SME's, let's take for Europe,

Siemens needs this technology, with the blockchain, Siemens supply chain just looks into the blockchain and sees "oh there Is a Portuguese company, and they are plug in on our decentralized software cooperative and we can buy from them and all in the click of one button", because the trust in the supply chain mechanism already exist on the blockchain, so now we open up the potential of SME's to very effectively engage with very big organizations for very little investment, in fact for no investment.

Do you think that that can also influence the HR role, if I need some expert, I just go to the ecosystem?

- Yes, I believe that every employee will be an employee of self. And we will sell time and knowledge. And we will be plug in a technology system that will distribute our time and knowledge as needed and as required, we might not know who the end customer is, but we know that we are giving out time and knowledge into a system that can send it out to the customer. So, now the opportunity lays on people who understand business, digital and technology and also understand the present, the past and the future

Speaking about the human resources again, we know that with technology a lot of roles are going to disappear, so what can be the new role and what competences will they need in the future?

- So, I talked about the past, the present and the future and the reason why I said this is because I remember a time when we did not have HR, when I started working we had personnel departments, and all they did was take your personal information and put it in a box, the function of HR was a management function, it was not a separate function. So, we look into the past were the function was automated.

Now we have the artificial intelligence that allows automation, so this is not going to stop, it's here, what we have to do is understand how we look at the world of business and accept those changes and value people on an organization who are people who can do the job

that robots cannot, on other words, people who are experts on keeping the robots working, and when I say robots I say automation, so the people who put the oil in the machine are going to be very valuable and that is the new job, and yes, it is a scary thought.

So, focusing in Portugal, do you think Portugal is ready for industry 4.0?

- No.

Okay, so what do you consider the main strengths and the main weaknesses of the country to adopt this?

- The biggest strength and the biggest weakness is the government. In Industry 4.0, and we will use the term for digital everything, there is no place for government. Because think about it, we can automate the medical system, so the management of medical records, social security, banking, finance, everything that the government does, and support can be automated and driven by artificial intelligence, so why do we need government as a regulator? The function operations of the government become automated so, everything can be automated, so, what do we do with all those people? That is the first question. So, the biggest strength is the government and the government by promoting Industry 4.0 is putting himself out of business, will that ever happen? No, because like accountants, they will find a way to exists.

Anyway, the biggest advantage that Portugal has, I believe is you guys, let's look into Ireland, people were emigrating, so it become regulated by the authorities, they thought "if these people are the future, then we need to have jobs for these people", so at that point, Ireland did a deal with Apple, with IBM, etc. etc.… they did a deal with all these companies to say "give us jobs" and we don't care what those jobs are and most of those jobs were taking a piece of something and putting it in another, what used to be called in Ireland screwdriver jobs, and that was what you did every day. And this was a training step and why we have every single technological company based in Ireland and, it is not because of corporate taxation, it is because we have an asset base and knowledge base of people who were especially trained. The same

thing can happen to Portugal, Portugal is losing young people all the time, so it needs to be a reason to bring them back and for the first time in human history we can do business on mobiles. Yes, Lisbon is great for tech startups, great for innovation, but that's it, it stops, what happens next? Part of work, part of Industry 4.0 that we are getting above, is the psychology, the mindset of how people are going to have to change as the work changes and as automation takes place. Portugal and the Algarve has great potential, great climate, so people can work in a climate, to have happiness, healthy work, but typically when we have lots of automation, people need to be able to be happy in their lives and need to make that change. So, when you have a good climate, because if you go to California you will see, most people say there is no innovation in San Diego, there is no innovation in Los Angeles, completely incorrect. Most of the medical innovation in The USA takes place in San Diego, most of biotech industry is based in San Diego, all you have in san Francisco is Silicon Valley, that isn't even in San Francisco, and it is there by accident, but if you go back to the 1930's/40´s/50's the innovation that took place in California was all in the south. So, we have the same thing here in Portugal, we have a beautiful country, great people who need a reason to get up, need a reason to get out and make that change. So, Portugal has the potential to start the new age of discovery, you did it before, you can do it again and I think with a few small changes, we can make this happen. We have it already in Lisbon, we have the startup revolution, a tech center and the web summit is a huge event as a first step. But when I go to Sevilla is a different mindset, and Sevilla is going to be the new tech center of the world and it is connected with rails, you can be in Madrid in a couple of hours, in fact you can go all the way from Sevilla to Berlin on a train, it's all connected. This is European policy, this is real.

I came to Portugal to work, I came here 25 years ago, I am on vacation now here in Tavira, but I am also two hours away from Sevilla, and Lisbon, in the last 5 years, got so expensive and when I spoke with other companies in my projects, Sevilla was more important

than Lisbon. But here is the interesting thing, we have Sevilla here, then we have Lisbon up here, you have a mountain in the middle that blocks Portugal from Spain, and here we have Algarve which connects Lisbon, Sevilla, Madrid, no mountains. The airbus industry has putted a big operation in Sevilla. Sevilla after the expo, had the expo site converted into a business park, and that is now a focus for technology, it has an incubation zone as well, but primarily it is focused on existing technology, so when I talk with people and I ask we can meet in Lisbon or in Sevilla, it is more important for them to go to Sevilla and this is a challenge that we have and this is why I think we need to move the technology out of Lisbon and bring it down here, that I think is the future. Spain is a big country, is a very powerful economy and I make the comparison Ireland and England, Portugal and Spain, except Spain is bigger than England. So, I think the challenge for you guys, for Portugal, is not to concentrate everything in Lisbon, but make that connection. And in Tavira, I have everything I need, like southern California, is the same, so there is a great attraction for technology investment. If I was to put in a data center, if I was to put tech center I would put it here, not in Lisbon and I would plug it into Sevilla as a supporter for the Spanish operations, rather than trying to support the Portuguese operations.

What are the topics you consider that need to be further explored regarding Industry 4.0 and the digital transformation?

- I think it falls in two areas one is education and the other is preparation, I don't believe that we are prepared for Industry 4.0 as a Portuguese society, this is some psychological thing, there is fear, there is a huge fear factor of automation. When you look at Portugal that does not have much industry to support employment, so when you put on top of that, that all jobs are going to be automated, the biggest problem here in the Algarve is the government, the biggest employer here is the government. So, the topics that are most important are education and preparation, we need to prepare the people and we need to prepare the businesses to make the transformation, Industry 4.0 is not going to stop, it is here, it is happening, so we have to get on

the train at the next station and make sure we stay on the train, because if we are not on the train, the train is leaving. We also need to have the support mechanisms and the role of government is to support, the role of the government is not to dictate. And education, the role of the government is to support education and also to prepare citizens to the transformation that is coming. Also, business society, groups within businesses need to come together, typically in the SME's sector, the greatest opportunity for growth in Portugal is via the Industry 4.0, you will never have an opportunity like this again and if you miss the train, then it is gone. So, business councils, chambers of commerce, etc. etc., need to come together and create a digital cooperative to educate and prepare their members for the change and to accelerate the change. Now, fortunately, with open source and block chain, everybody can play with it and structure it, so I think with creating these technical expertise centers, these technological coops, will have the expertise to distribute the knowledge to the business sector and they have the time to focus on their business while learning how to do business and so they don't have to make an investment of cash, they only need to pay a small membership fee of the coop and that membership fee provides them with the information and the knowledge to do digital business. And in Portugal the biggest problem is going to be the mentality change. Government has to support the change, by making regulation that helps businesses. We need a new revolution and an evolution, so we need to re-evolve to make the change, it is not going to be easy, it is going to be very difficult and I believe it can happen and I believe that by connecting communities we can make it happen.

The first question when you talk to a small Portuguese company is "the Portuguese consumer cannot afford to pay, they are too busy trying to survive.". If I would to base my business here in Portugal, I would be broke. But yeah, we need to understand how to make the change, but by helping small companies, and invest the first question is "how much is this going to cost?" we need to make the change, so the cost is very small and to show that what it implies

is much bigger than the initial cost and I don't think that can happen until we can provide the structure, the technical structure for companies to do that. So how can we make the technology available in a center, so everybody can buy a little piece as they need, so business can adapt in small, manageable steps.

Once again, thank you for your time and valuable insights.

Expert 3 Interview

Job Title: CEO

Interview date: 22nd of September of 2017

Interview local: Face to face interview

Interview length: one hour

Good afternoon. First of all, thank you for your availability to share with me some information. I am doing my thesis on Industry 4.0 in Portugal and I would like to know your view on this topic in order to understand your perception and analyze the level of adoption of the Portuguese industrial sector. Therefore, I have a set of questions I would like to ask you.

So, first question, what is Industry 4.0?

- First, what is industry? Industry is, you pick up the first sector, which will get the raw material, such as iron, lithium, oil. From that first sector you get the raw material. Then you get in the third sector and you say, "I want to sell this cup of coffee", and what the industry does is if you want to sell the cup I'll have to transform the materials into one product and deliver. Therefore, the industry is stuck between these two, the final customer and the raw material. So, and this is an important thing to realize, is that the industry does not live isolated from itself, it lives thinking about market needs and constrained by the raw material availability. One of the

most important things in the industry is that we often want to deliver something, but the raw material is expensive and so, we must think of alternatives.

The first thing is that the industry does not live in a world apart, it is constrained by these two. If you do not sell paper, you need to reduce production, if production is low, then you have to understand how to rebalance the production unit, how to rebalance shifts and everything. I'm just talking about production, I'm not even talking about development and product. But the whole industry encompasses this.

The whole industry understands that in the end you want this cup, but you do not know how it was done. The industry will have to draw the cup, see how it is produced, produce it and deliver. Then you distribute it to the stores and do the marketing. But the industry does all this process, it has to go sourcing, it has to go see the raw material, see where it is cheaper, draw. It does it all and you have to be always monitoring, you must always be seeing the price of raw materials because of costs because the company makes a contract for 5 years and cannot sell the cup at the same price for 5 years, so what if the raw material price increases? You lose margin, are you selling to lose money? So, you have to monitor this cost. And this is important that you understand because Industry 4.0 is that.

Industry 4.0, you have to see it as a platform, which lets you see the complete life cycle of a product, and when I say complete life cycle, it is never a complete cycle in a factory, it is the complete cycle that you monitor and that includes the whole upstream and downstream of the supply chain. Okay, you can have AutoEuropa here to assemble cars for then sell, but AutoEuropa has a number of first-line suppliers, for example Bosch, which are companies who provide them with systems, such as a gearbox, so it already provides semi-complete systems, which then they bolt in the car. Then the second-tier suppliers are the ones who provide the smallest systems and you also have the parts suppliers, which only provide a little system. There you go, you have it all.

Therefore, industry is this whole complexity, you are stuck between two sectors, because the first sector only has to worry about what the industry is asking for, it does not care if it sells, if it does not sell. The third sector should only be concerned with marketing and customer analysis. “What does the market want me to do?” And say, "give me this." So, the industry to function has to understand how these sectors work and has to understand its own industry, its own complexity, all its supply chain and all the problems that it has, if there is a strike in a place, if there was an earthquake in another, if there is raw material in another, if there was something lacking in quality, you have to realize all this, because in the end, if you have cars, for example failing the recalls of the automobile industry, why did they happen? Was it bad design? Was it some supplier who is doing something wrong? Was it raw material that was not supplied with quality? And you, nowadays, take a long time looking and discovering the problem.

You have to contextualize the industry 1.0, steam engine, industry 2.0 of Mr. Henry Ford. Because the problem is that you, in the steam engine, you had a whole car stopped and then you had the same guy, ranging from bolting suspension, seats and everything, so he was not specialized at all, it was not efficient. Mr. Henry Ford arrived and said, "no, no, I'm going to need a guy just to screw the wheel”, then this guy is going to be a lot more efficient at screwing the wheel. The 1.0 is mechanization, that is, instead of being manual, it is steam engine, in other words mechanization, in terms of power. Industry 2.0 is the specialization. Industry 3.0 is the automation, and this is important to realize because, to have a tablet in my factory that says how many units I produce is industry 3.0, this has been done for 20 years. Industry 3.0 is a fully automated industry where I have total control. What is the difference from 3.0 to 4.0? Is that 4.0 has the context. That's why I'm telling you the 4.0 is “I do not live locked inside my factory”, but I look at my supply chain, look at the raw material and look at the services. That's why it's the digital platform, that's why it's a platform industry. It is different

because in Industry 3.0 you only look at your own factory, you're only worried about the production line.

Industry 4.0 is not making websites, it's not automating, it's not doing any of that, that's 3.0! Of course, you can say, “but nowadays I can put artificial intelligence in a robot and the robot realizes that this is a car” that's fine but that's industry 3 and a half.

The great thing about industry 4.0 is the context, you actually understand when you are manufacturing, and your own machines perceive the context and make the decision. For example, imagine you are making 2,000 cars a day, and then suddenly your sales fall. Your sales say, “I do not need 2,000 cars, I only need 1,000” and you know how to reorganize the line almost automatically. And this is going to mean that instead of having 3 shifts I'm only going to have 2, it means that my supply chain is going to have to produce this and it knows it before I do. Nowadays, this little thing, if sales tell you this, it is a nightmare, because you have to talk to everyone, then the other can’t and bla bla... The story of the industry 4.0 is to say “okay from 2,000 to 1,000” and the machine even starts to see that there are problems of demand, it knows, and you can start to do some preventive things. Because you are reactive today, because the industry works very specialized, you have that guy who specializes in the door handle of the driver, then you have another that specializes in the handle of the backdoor... and the true Industry 4.0 says, okay you continue specialized, but I will give you a vision that allows you to make quicker decisions, because nowadays we are not preventive at all. The recalls only happen because, we only know in the factory that the recall happened, because the guys from the aftermarket blew an airbag, “oh no problem, killed two, then killed three, what a bummer, it killed 20, so it seems that there is some problem”, so when we get to the factory the problem is already enormous, because if I had identified at the beginning, instead of producing 1 million cars, I had only produced 100,000. So instead of the recall costing me 5 million it costs 50.

So, the vision of Industry 4.0 is to make everything much more efficient, it's dramatically lowering costs, and when I'm talking about dramatically, I personally estimate at about 70 to 80 percent cost reduction. Industry 4.0 is very efficient to do things, nowadays you cannot. Nowadays, if you have a problem, you continue to produce, because you never stop producing and then you have to walk back and realize the millions that you lost. And this is the problem of Industry. It is very good because Industry 3.0 allowed this, Industry 3.0 allowed industry to be very good within this pattern of I have this spoon and I am very efficient at producing this spoon, however if there is something wrong, I lose a lot of money. And this is what Industry 4.0 allows you with artificial intelligence, because it is preventive. Industry 4.0 will not improve the spoon, this is 3.0, 4.0 will allow you to detect problems as soon as possible, predict problems and be very preventive, so you are not a firefighter, but solve everything almost when the problem is still at the beginning, because these costs are gigantic.

So, where do think Portugal is in terms of level of adoption?

- What is the problem of Portugal? Portugal is not a country of end-product industry, is a country of pieces, you never deliver the complete product. You always send this to Germany or anywhere, you are not a product development industry. The national industry, it was not it who designed this cup, this cup came from Germany. The national industry is an industry still very 60s, 70s, 80s, cheap labor, we are cheap guys in Europe and we are not very far as china or India. So, we are cheap as the Chinese or the Indians, but with the advantage of being in the same time-zone. When you're going to do a national industry pitch, you're not going to say that we're good at drawing, that we're good at this and that, we're cheap, and we're here to help you, you just have to get on a plane for 3 hours to Portugal, while in China is a complication. And that was something that positioned us well in Germany and in these big industrial centers, because they say, “okay the guys are only half the cost here in Germany and they are close”, because in Germany I travel from one place to another and it's almost the same time as going

to Portugal. However, Industry 4.0 can give you an industrial change, but you have no policy for that, that's it. We are a country to this day cheap, my guy on the line costs 600 or a thousand euros a month, half the price of Germany. Problem with this pitch is that it means that you do not have control of the value chain, because you only participate in a specific part. The whole Mercedes' margin, it is high because they will sell the car, okay it compresses manufacturing costs, development costs which are also more or less fixed. As Portugal only manufacture, you do not have the project, which means that you do not have the brand, you do not control the value chain. So, the problem of our industry is that it is an easily understandable industry, because we do not have development, we do not have the chain, we manufacture, we do not decide anything, we only manufacture. And in Industry 3.0, AutoEuropa came to Portugal and helped us a lot to improve procedures, 6 sigma and ISOS, so we got really good at Industry 3.0. we're good at doing that. But the Industry of the country has no margin, we are literally slaves of the others.

The industry 4.0 by opening the book and allowing us to look at the context, potentially allows us to start developing, that is, we dramatically change the way of our industry sector by being able to control the value chain more. Since industry 4.0, through relatively inexpensive technology, let's you have control of everything, so why not start developing? It does not have to be cars, but maybe there is a lot we could do in the middle, have product and brand, because in the end you control the price. This is the opportunity.

There is no industry 4.0 in Portugal. Implement industry 4.0 in Portugal for what? If I do not have a brand.

So, can public policies influence the adoption rate of Industry 4.0?

- You have two fundamental questions: public policies that help you go into Industry 4.0, that is, the Portuguese 2020, financing mechanisms. So, today the public policy of Industry 4.0 is nothing, it's just take a lot of money, some subsidies, to see if you can make it, because

you have no margin, so take some subsidies to buy some machines. In other words, public policy today, in theory, says that it is Industry 4.0, but in practice is, takes subsidies.

It can take infinitely in extreme case, or very little, it is a question of how public policies can be catalysts or not of this change. This is number 1.

The number 2 is all about brands and branding, now for example with this hype of startups, you can connect it all. They have their own brand, you go to the platform of Uniplaces, the brand is theirs. When you buy a car, you do not know that you have a mold of Ibero molds of Marinha Grande. Startups have already enabled you to start this branding story. So how can industry start having its own brand? We must focus on some sector, we are not going to make space shuttles, nor machines that cure cancer, we cannot be megalomaniacs, but we must see what is available and where we can focus and try to create the brand, an international brand, because when you control it, you control the chain, and when you control the chain, you control the margin. You are not being a slave, but it is you who control your margin.

So, Industry 4.0 to be effectively implemented in the country, it is a matter of public policies, because Portugal is a small resource country, the bank does not finance the companies, therefore it has to be the government to create public policies of industrial funding. And second, if Industry 4.0 is implemented, you can control the value chain and raise from small company to medium from medium to big, so you can improve the margin, which means that businesses become more profitable, and more profitable means that the government has more money to carry from IRC's, which means that companies can pay better, and this creates a virtuous cycle.

Therefore, Industry 4.0 is an opportunity for the country to do this, but is the same opportunity for Portugal as for all other countries, so the more you postpone, the less you will seek this opportunity.

So, there is no answer for when Portugal can implement the industry 4.0, because the ceramic sector is not even at Industry 2.0. If you go to a ceramic company, there is almost no

automation. In the automobile it is Industry 3.0 yes, but in the traditional sectors, it is not. The textile is not there, when you need to make shoes, you get the workers you need and you do it. The Portuguese industrial scene is not standardized. As soon as you answer this question the first thing you have to see is that it is not standardized. But with public policies we can try to standardize more. As Portugal is a small country, we need to focus on public policies, companies do not have much money and public policies have to be there for that, but it should be more demanding, the government should only give the money if companies produced x amount. So, the state has a lot of power there. In Portugal, a small country, if the government does not want to do things, they do not happen. Look at Industry 3.0, the automotive sector, it only happened because AutoEuropa settled here, okay you had other companies, but they were not so demanding. We only got good in the mold industry, because AutoEuropa came and demanded ISOS and all quality standards. In fact, it was a public policy in the 90s that brought all this.

Portugal is not like in the US where the ecosystem itself can generate enough funding to say okay, I do not agree with Trump I will go my way.

You have no capital here, you do not have the money to say I do not agree with the government I will go my way.

The Industry 4.0 also allows to increase the so famous productivity. Why is Portugal worse off compared to the Germans if we work longer hours? Because German sells Mercedes, which is the final product, so every hour of it, because productivity is revenue divided by the number of workers, Mercedes' turnover is much higher, so even if they work less, productivity will be much higher than ours, therefore the employee can only work 4 hours but he has a lot more productivity than we have even if we work 20h. Productivity means, if you control the chain, you have bigger margins so you can work less, that's the whole theory.

With Industry 4.0, because you are technologically connected, allows you to do it more easily. And the government literally has to force that to happen. Because we will talk to the Portuguese industry to see if they want Industry 4.0, and they do not want.

And obviously the role of the startups is huge. Startups are digital platforms, if the Industry 4.0 is a digital platform, so you connect the startups that make the platforms with the companies that own the machines. And digital platforms allow them to move up the value chain, so startups give them the tools to climb. Instead of being them receiving the tire from Germany, they are developing the tire.

What are the main technology required for industry 4.0?

- Clouds, number 1, you no longer have your data centers, you want everyone to store data in the same cloud. You have a data center where you have centralized information, so you do not have it in silos and nobody updates anything.

Artificial intelligence is another enabler, because you want to predict, and you do not want to be dependent on humans, you want the system to say "attention I'm detecting an anomaly, come and see" it's a decision support system, it says "based on my algorithm, I think you should do this", then you decide.

So, when people say that with Industry 4.0, we will all be unemployed, that is not true. People grow in size of value, you stop having the guy that is only screwing, but you have a series of systems that each one asks for the decision of others, people who decide, so there is also a paradigmatic change in the way the staff is in the industry, so obviously it will mean unemployment in the perspective of direct unemployment in the Mercedes, but it will mean employment in startups and companies that provide technology. But, when you need to screw something, then it's the robot.

There is no disappearance of jobs, but there is a transfer of jobs. A factory with 10,000 employees will never happen again, you have 1000, 500.

IoT's, internet of things, because it is what allows you to connect, you receive the information, you store it into the cloud, the artificial intelligence processes information and delivery. These are 3 tools, and of course you need cyber security on top of this.

CPS's is IoT because you have the sensor that captures a physical thing, a temperature, and then sends it to the cloud. Then the AI says okay this temperature is good or bad, so do this or that. The IoT is to connect this to the internet, then you need the algorithms and that AI, this means that. And all this is stored in the cloud. The CPS is what joins IoT, AI and the cloud. And then you need to be safe. We have an opportunity, but there is still a long way to go.

If you had to estimate, how many years do you think it will take Portugal to have fully adopted Industry 4.0?

- The automotive industry is evolving very quickly, so if the regulations do not block all of this, 5 years from now we will have autonomous Uber and everything. Industry 4.0, I think it will evolve gigantically, I say that in 2017 things have already accelerated tremendously and will accelerate even more. So, either we wake up and adopt industry 4.0 before 2020, 2021, until fully implemented, or we lose the train and we once again cry and come back to a financial crisis. We have to be fast because everyone else is acting very fast. Worldwide Industry 4.0 will burst. You have to start to change already because the others are also changing. The national industry will have to take a risk, because from the moment you are designing and not doing what others want, you are at risk, and the Portuguese industry was all this time without risk ....

Once again, thank you for your time and valuable insights.

Expert 4 Interview

Job Title: CEO

Interview date: 14th of October of 2017

Interview local: Non- applicable – Skype Interview

Interview length: Thirty-four minutes

Good afternoon. First of all, thank you for your availability to share with me some information. I am doing my thesis on Industry 4.0 in Portugal and I would like to know your view on this topic in order to understand your perception and analyze the level of adoption of the Portuguese industrial sector. Therefore, I have a set of questions I would like to ask you.

So, first question, what is Industry 4.0?

- I think there is a problem in understanding what people think that Industry 4.0 means, because they understand Industry 4.0 as a context of industrial scene digitization and, anyway, it is one of the elements, but it goes far beyond that. Industry 4.0 essentially deals with two things: it has to do with demand on the one hand, that is, consumers want and demand more and more personalized products, products that are unique and they are not willing to pay more for that. That is, we are no longer talking about a universe called mass customization, in which we had basically the same products, only with small customizations, color, or 3 or 4 variations of material, etc., we are talking about scenarios, some a little more futuristic, but that already happen in some areas, from customers who demand products that are really unique, unique in terms of shape, in terms of characteristics, etc. So, the first revolution has to do with this and not so much with the matter of factories or digitization or whatever, so that is the first point.

The second point is that from the moment someone makes a purchase of a product that is unique, there is a manufacturing order that is given to a factory and then the factory has to

get that product and deliver it to the final customer within a specified period and within a price that has to be competitive. And therefore, the Industry 4.0, what advocates is that there is a revolution that also exists on the technological side that will make it possible to make this delivery timely and so unique. And how does this happen? On the technological side, it essentially has to do with the revolution that existed in the area of electronics. From the point of view of electronics, electronic devices are nowadays becoming cheaper and smaller, which can be attached to any product that is being developed, so this is a starting point. This electronic today is capable of sensoring, communicating outside the company, it has computational capacity and is often able to work on the product itself. When we are talking about this, we are talking about the so-called IoT, Internet of Things, which in an industrial environment is called IoT, from the moment we have this electronic attached to these products, the whole management of a factory is done in a completely different way from what was done until today, for example, it is enough to think that if we have a factory that works entirely with unique products, it is no longer possible to optimize the factory because an optimization of a factory is done from tasks that are repeated and that can be sequenced, and that can be added in a certain way so that optimizations can be made. Now when we have a process of this sort, this is going to change completely, and these systems that are in the background attached to the products that are an electronic component, even before the product is made, already have all the specification that came from the customer. It is the product that will later know throughout the manufacturing process, the processes that have to be executed in itself until it is produced and, therefore, this is a great revolution and it is evident that this is possible only by using technologies from both the software point of view and from the point of view of electronics, which is the most recent.

So, Industry 4.0 is this scenario, in which the factory then organizes itself, because then we have intelligent data inside the factory. When we are talking about products, and these

products that have electronics are now called cyber-physical systems, which is something that is at the origin of the topic Industry 4.0. So, we have cyber-physical systems (CPS), which are the products, we have production machines, which do the transformation steps, which are CPPS, cyber-physical production systems and then both are sensorized, they can communicate, and what will happen inside a factory, is that they will autonomously organize. So, what is going to happen is the so-called market place. The market place in the factory, is where the product will ask a set of machines what is the price to make a certain manufacturing step, the machines will respond and there will be a dynamic allocation between one another, so that the material moves to the manufacturing stage and the manufacturing stage then performs the transformation that is necessary to execute, so we are talking about IoT and we are also talking about Industry 4.0 in the industrial environment and after that everything extends to the whole chain, so then, there are the factories that will work with the whole market place, the whole supply chain and the whole range of materials, from raw materials to final customers. Now, when we speak of Industry 4.0 in other contexts, in Portugal or somewhere else, there is very little understanding about all this.

Speaking of some technologies, can I consider that the CPS are part of IoT?

- Yes, IoT is a bit of an abstract name, it came from marketing, but it simply means that the products are connected to the internet and can transmit information to the internet. Cyber-physical systems are a little more than that, it's about giving intelligence to the product itself, so it's not just the issue of communication and sensoring, but it's the intelligence of the product itself. Even in the future we can have products that influence their characteristics dynamically in function of information about the environment, depending on some request that comes from outside. In addition to intelligence and computing, it is much more than the Internet of Things. The Internet of Things, we are usually thinking about the consumption part, we often talk about the smart refrigerator, so we are applying to a more general and much lighter context from the

point of view of definition, and the CPS is much more than that, it is in fact, to endow the capacity of such intelligence into a product that it becomes possible to have a digital mapping of everything that happens in the physical environment, there is a term that maybe you have heard that it is the digital twin. The digital twin is the background of this, it is me being able to have a computer model representative of everything that happens in a product and this also applies in the context of the factory, therefore, to do a digital mapping of everything that happens in the factory and we enter into the processes of digitization of the manufacturing world, which is generally understood in Portugal as the industrial revolution of Industry 4.0.

So, which technologies are crucial to implement Industry 4.0?

- I already mention IoT and CPS, those are the big ones, we also have the cloud, all the software part as well.

What are the biggest challenges for companies to transition to Industry 4.0 in Portugal?

- Well, there are those who influence and those who should influence. Those who should influence should be those companies who saw the need that they can only compete in this world of more and more unique and globalized products, with greater flexibility, greater quality and greater efficiency, this should be the real reason for companies to invest in this area, because often in the domestic industry, as there are quantities of materials that are made in large series and then blend into small series, there are many companies that are not even able to attribute the price, know how much is the cost of making that product in a differentiated way and these companies either quickly invest on digitization processes or they will, in no way, be able to compete efficiently in these markets. They could either keep existing for a while in niche markets, where it still makes sense to have products in long series or they will disappear.

Yes, and the Portuguese industry is not homogeneous in the digitization level, which is also a problem.

- Not at all, I think there is a very important basic problem in the Portuguese industry. It is the fact of decision-makers not understanding the technology and not understanding the value of the software area, and this is already a problem that has some time, it means that the industrial world can very easily realize that if you buy a machine for a certain process the machine is faster and therefore, they will get more income from this machine and so, they are able to make a big investment to buy it, but if you have a similar investment in software and that will allow them to achieve a productivity level equal or greater than they can with a new machine, they do not do it because, on one side there is a machine and they think they have a tangible asset, there is something they can see and that is theirs, and on the other side, they have software that is intangible, which is not palpable and therefore this is very complicated. This will only change, when people of a different generation begin to reach the decision places of the national industry companies.

Which companies/industry sectors are the most affected by Industry 4.0?

- Industry 4.0 is born essentially in Germany and as it is born in Germany we are usually talking about the automobile industry and the area of industrial equipment, therefore these are the areas that are more prone. Many times, companies want to do something, they do not even know what it is, but they are only doing it because everyone is doing something regarding Industry 4.0. But the pressure is mainly felt in the automotive industry, which is not a pressure that arose today, but the big manufacturers of the car industry that make the assemblies of the cars in the final stages have a long chain of suppliers and, therefore, there the pressure happens regarding quality, price, cost, competition. This happens a lot in the areas of automotive suppliers, even more than in the OEMs. But I would say that this is the area that makes sense, at least in Portugal, and has the greatest pressure. Of course, in the international context there are other areas, such as electronics, semiconductors, pharmaceuticals, and other areas where this is very important too, but here in Portugal they have less pressure.

And where is your company in the Industry 4.0 ecosystem?

- What we do is processes of industrial management software that map and generate all the elements that are within a manufacturing line, therefore, when we have production, equipment with specific routes, materials, with consumables, etc., all this is managed with our software, from the highest level of integration with SAP until automation, in which all processes are automated, meaning that there is an integration like machines or devices. It is what we call the backbone, which we call the core of Industry 4.0, because we have built a way to map the physical processes in the computer, in a system, in order to then have all the data, given in real time to act on the processes, or given in offline mode in order to be able to update and change the efficiency level, productivity, quality of production and you can measure the entry capacity of new products into new markets.

So, what we do is the basis of what should be the main areas of development of Industry 4.0, of course there are many parallel areas where we do not focus, we are not in the electronic part, that directly influence the IoTs, we are not in the part of big data analysis, or 3D printing, so we are not in a lot of areas that are Industry 4.0 areas, but we are in what we think is one of the fundamental elements of any Industry 4.0 strategy. And then there are many who are in the same area, so we compete with differentiation.

And do you also have customers in Portugal?

- Very few, but we have. Last year, we had something like 1% of the national market.

And that 1%, how do they look at this new reality?

- I think that the 1% that we have are the exception cases, that is, they are companies that manage to have this vision, that they realize that it makes sense to invest in this area, because in the long term it will not be possible to compete in another way. There is another aspect here that is, there are more companies that we deal with who want to do things related with Industry 4.0, the problem is that they do not value it as much, so they cannot perceive the

level of investment which is necessary for such a thing. Then, they make other smaller or partial investments that help, but will not solve the whole problem and think that they are having a 4.0 strategy… and maybe they are but cannot see the type of investment they have to make, because these are some heavy investments, it depends a lot on the size of the company, but they are big investments.

What do you think will be the main impacts of not adopting Industry 4.0 technologies?

- Either you will be able to work in niche markets or you will disappear.

Talking about employees now. What could be the "new" role for the remaining human resources in Smart Factories? What skills will they need?

- In a pure Industry 4.0 scenario, the repetitive jobs made by people are going to disappear, because the repetitive jobs become fully automated. Now the problem is that in the Industry 4.0 scenario the products are unique, they are all different, there is no automation that exists to do this, there is no intelligent robotics that can do all this, and I think there is a lot of misinformation here, there was a great fuss that arose from the World Economy Forum, which in a way was positive because it drew attention to this area and made everyone focus attention on these topics.

So, these repetitive jobs that will no longer exist, will be replaced by other types of work, so for example there is a very funny example that I like to mention that is a situation from Mercedes in which Mercedes, in one of its most flexible factories in Germany, replaced all robots with humans, because they were the most flexible resources they knew, and this is an extremely positive message in this context. Of course, in a more normal context and what will probably happen in the future, will be collaborative robotics, which basically means, when a new request for a completely different and unique object is presented, there is a person who does the initial setup of this product for the first time, this process is made by a person and then there is a robot and the robot learns and at some point starts to do the second case and the third,

the worker will still be there to correct some aspects and at one point the robot is alone, until a new product comes again and the worker enters again. So this to say that, there are general repetitive functions that will cease to exist and others that will be created, from the point of view of skills that are necessary for these areas, I think there is also some confusion there, of course there are areas which are completely new, either in the area of information systems, or in the area of data science, data analysis etc., but it is not the manufacturing operators that will become to be data scientists, so there are a number of functions that are new and will come to exist, areas of artificial intelligence, deep learning, etc. that are areas for people with more skills who are in the areas of sciences, applied sciences. In the view of the other functions what is needed is some technology knowledge. But I find it funny because I've been in some debates and I see some business owners saying "no, but people are not adapted to work with new technologies", but in a modern factory with new technology, working with a system they have is the same thing as working with a smartphone. So, most people, regardless of their social class, have smartphones, know how to work with this type of technology and the learning cycle is very fast. Therefore, I think that those who really need to learn are those managers who are in these areas, as it is evident that there are people in the manufacturing areas in which the transition will be easier than others, but this revolution is not going to happen tomorrow. It is going to take some time, and until it arrives, some of these people will acquire new skills and will be transferred to new areas and then, there is a large part that is going to retire. Actually, one of the things that is very interesting in Industry 4.0 is that Industry 4.0 is something that is supposed to happen, so it is almost futurology, so it will provoke what is called self-fulfilling prophecy, which is what everyone thinks it's going to happen and that's why they're going to invest so that it actually happens. However, now I do not have that catastrophic vision of job loss, even though there are functions that are repetitive and others that are not repetitive, there

are areas that will never be automated, even if they are not of great added value, as gardeners, plumbers, will never cease to exist.

Focusing again on Portugal, what do you consider to be the adoption level of Industry 4.0 in percentage?

- It's low, I'd say 10%, or less. This was also noticed in the government Industry 4.0 initiative, that they tried to launch. Which ended up creating some initiatives, one of the main ones that are currently happening is the "vales Industria 4.0", where companies receive 7,500 euros to do something in the area of digitization and what the companies are doing with this are websites, it is better to have websites that not to have, but this is where we are investing the funds for Industry 4.0.

And how can these public policies influence the adoption level of Industry 4.0?

- I do not really support direct public funding on these things, other than by positively facilitating, promoting, but not necessarily financing. I think funding has sometimes some detrimental effects, I think it should be shown, I think that there should be model factories, for example, as there are in other countries, where anyone can visit and see how they work. I think there should be a promotion of the training offered in these areas in Portugal, or a promotion of the national companies themselves that have solutions in this area. I think that there should be a set of measures that may even facilitate taxes, for example, tax measures to encourage research and development, but well… these actually already exist and are quite aggressive. So, I think the main thing would be to show, promote and contribute to education in general, instead of directly funding for the digital improvement of factories, but this is my opinion.

If you had to estimate, how many years do you think it will take Portugal to have fully adopted Industry 4.0? (meaning most companies have integrated Industry 4.0 technologies)

- It is very difficult to predict. Industry 4.0 in Germany appears in 2011, here in Portugal the first national program of industry 4.0 occurred now, in 2017, so only on this point we have 6 years difference. And then the starting point itself is already very unbalanced, so Germany was already far ahead on the previous processes, which have come since the third industrial revolution, from the use of PLC's, the use of computers and some kind of robotics, so it is very difficult to know how far we are going to get or not to be in parity. I would say that we are a few years away. But, since that this industrial revolution is much more based on technological mechanisms that are not so capital-intensive, this might suggest a faster adoption than in other cases, anyway I do not know. Now there is another thing that is also important to mention that is a company has a lot of work to do in maturity of industrial processes, even before introducing these issues of digitization. Because it is not through a computer program that a company that is relatively disorganized and that has no maturity in its processes that will happen to have them. I often say that automate the non-mature processes, is what it's called a little "garbage in garbage out", so you have inefficient automated processes, which I do not know if it's necessarily better. So, this is all to say that I cannot guess the adoption time, but if I had to throw a number I would say 20 years from now.

Can you recommend other specialists in the field with whom I should get in contact?

- In the area of IoT, there is a professor of Aveiro university, and also the head of Industry 4.0 in Bosch Portugal.

Once again, thank you for your time and valuable insights.

Expert 5 Interview

Job Title: CTO

Interview date: 26th of October of 2017

Interview local: Non- applicable – Skype Interview

Interview length: Thirty-four minutes

Good afternoon. First of all, thank you for your availability to share with me some information. I am doing my thesis on Industry 4.0 in Portugal and I would like to know your view on this topic. This talk would focus more on Germany and see if there are some indicatives that Portugal could withdraw for German's example. Therefore, I have a set of questions I would like to ask you.

- Now we are talking more and more about Industry 4.0 and it is more of an evolution than a revolution, I'm not sure if it really needed to classify that way, but that's what is coming, this industry, but yeah Industry 4.0 is the name they are using and is basically about making the machines smart and connecting together. It is the networking, networks being developed between the machines. I would say in general, for the technology, the very important thing is this interconnecting of things together and creating networks, if you look for a more academic or philosophical point of view, this is basically how nature in general develops. Nature, in general, you have small units there that interconnect to each other like atoms and molecules and they build organisms, so these organisms communicate to each other, they build networks, but if you have one organism, this one organism also tends to communicate with other organisms and you see that everything that is somehow common to nature is connected to the networking. So, the most complex thing that nature have ever, if I can say, developed is probably a human brain and the human brain consist of interconnections and connections between the cells, the pure interconnection, that's the brain. So, that's why the interconnection imported to

technologies, in general is the right way to go, all we have to do is learn from nature and we are learning now because we are doing it, following the nature, connecting all the machines together and building a network because we know that the sum of the parts of the network are bigger than the number of things being connected. There is something that is called induced intelligence that is coming from just interconnecting stuff. If you look at the bees or ants, it develops some kind of intelligence, but it is only there because bees and ants are together and are connected to each other, if you disconnect them from the bundle of the society, you will see that they don't have that big intelligence, but once they are in the society, they can do some huge things that people cannot understand how intelligent it is. Same thing is happening with the machines now, machines are interconnecting, machines are learning, machines are going to be able, that is the next generation, the 5th one, the machines are going to be able to build next generation machines. So, until the industry 4.0, including the 4.0, we have a human driven technology development and in the industry 5.0 we are going to have a machine-driven technology development and the machines are going to improve themselves. That's my point of view on the whole thing. But we can also go deeper into the technologies and the German point of view. So, Germany was very strong in industry 3.0, it was the strongest for industry 3.0. Machines, precision machines being able to build more precise things. Germany had a big problem, or as we say in Germany, missed the train. We missed the train once Americans took over the race with the internet and developed it and embrace it for themselves. They built huge industries based on the internet and also huge companies. And we see it, from Germany, that we have kind of lost that race, but what we understand here in Germany, is that in the next revolution coming, with the machines interconnected, creating the new generation, the new internet, as we call it Internet of Things. So, Germany has a huge chance now of becoming a leader again in the technology development, that is why industry 4.0 is a huge chance, for Germany and that's why there is this Industrie 4.0. This industrie 4.0 is a project from the

German government to create a platform that is going to help becoming a leader again in this area and that is why Germany, with that program, is investing a lot of money, we are talking huge billions here, it is 200 billion euros invested in the development of Industry 4.0 in Germany. Because Germany knows if we lose the second race now, we are going to have huge problems as a nation and as a country, huge problems in terms we are not going to be able to recover from it, so it is something that is not an option is just a must. So, it is not only industry 4.0, but this industrial IoT. And you probably will have to talk about IoT generally right? And you have to explain what are the differences between IoT, industrial IoT, Industry 4.0, and if you touch Germany you would have to go into the projects and programs Industrie 4.0 and horizon 2020. Horizon 2020 is a program from the German government to provide a platform, to provide the funds for the development of the whole Industry 4.0. So those are the aspects you have to consider in your work. So that's my view from the German side, it is just not an option or opportunity, it is a must. Something that Germany must do in order to stay in this race.

So, you were mentioning the IoT and one thing that I've come across is some confusing regarding IoT and CPS and can we consider that the CPS are a part of the IoT?

- So, first there is a question of what you consider cyber-physical systems. Can you give me your definition of CPS? So that I can tell you what is my opinion.

So, cyber-physical systems are what is connecting the physical and the digital world, and they are a set of different objects, like we have the sensors, the actuators that are collecting data from the physical world and sending it to the cloud and also analyzing it, so they can react and adapt to the environment, and they are connected through the Internet of Things with the different protocols and connectivity networks.

- If that is the definition, then I would say there is no difference between cyber-physical systems and Internet of Things or the things. The things, in general, or the smart things do

exactly that, yes, they are connected to the Internet, there is an interconnection between them that can send information to the cloud, you can analyze the information there and you can control it, and do the machine learning, big data. Also with the actuators, or engage some actions, so if that is the definition, the I would say, no, no real difference. Let me see, there could be a different point of view that, but it's pretty hard for me to find a different explanation, I don't know, we can talk about it, you can tell me what are the opinions to say if they are true or not.

Yes, because some authors actually think they are the same thing, they are aliases, we can say that IoT and CPS are the same, and others don't even mention CPS, they just mention their components like sensors and actuators and then, we have other authors that actually define the Internet of Things as being the connectivity making this possible for all objects being connected and sharing information, and that the cyber-physical systems are like the objects, the sensors and actuators.

- I understand, it is the differentiation between the connectivity and the physical-systems. Because I think mainly the name Internet of Things is misleading and the term could be interpreted as being just the connectivity, the connectivity like the Internet that we have and according to that analogy, IoT could be also the connectivity of the things or the cyber-physical systems, to be honest I am also not sure, I never used CPS, I use Internet of Things. And when I'm talking about cyber-physical systems I would call it a thing, a smart thing. But that could be only my point of view.

So, you are related with Industry 4.0 because of your company, right? Do you have clients outside Germany or it's mainly German clients?

- We are focused at the moment in the German market. We are a company builder, a IoT company builder. And company builder means that we invest in companies, provide the

technologies, or create the environment where companies can be developed, and we build companies that are concentrating mainly on German market.

And when you are working with these companies what are the biggest factors that you see that are influencing the adoption of these new technologies to transition to Industry 4.0?

- Internet of Things in general, must solve problems, must help. The systems are being easier to be used, if we are creating more complex systems, in that case, the systems are not accepted by the customers. The customers could be companies, or could be just simple users. I think the biggest problem is on not understanding what this exactly means. The understanding of user centric technology development. Mostly, companies do develop technology, they don't develop the products that solve problems. They introduce small problems, I always give this example of smart coffee cup. I have a coffee cup, and you just drink your coffee, it's fine, it works, there not a huge problem, and now you want to develop a smart coffee cup and you connect it to some radio transceiver and then you connect it to the internet, to a cloud solution, and then you have an app, and you download the app, you register yourself and you go to their portal and you set up, and when you drink your coffee you can get some information and the thing is this is just too complex and is not solving any of the problems that you have by drinking coffee, is just adding more, these kinds of products can never be accepted and that is the main problem of most products we have out there, that they are not user oriented, they are not solving problems, they are introducing more. Same thing also for the Industry 4.0, if it not helping to improve the production, to bring the machine to the level we talked at the beginning, that the machines are able to interact, communicate, negotiate and make decisions, I think that the connectivity is not going to help anyone, and it is not going to be accepted, because it is just not solving problems, it is creating new ones. That is the main reason. The other reasons are that all industries, for example here in Germany that is often the case, are very traditional ones, that the people have embraced the technologies as they are and they believe that this way of

working cannot be improved and if it can be improved, they are also afraid of losing jobs, that people are maybe at the age that you cannot easily learn the technologies, when you cannot easily change your habits, and in this situations it is hard for them to accept anything new, which is historically seen, it is nothing new. We always say that these historically problems always existed, of not accepting new technologies. For example, when Thomas Edison invented the light bulb, people did not want to accept it because they believe they were getting headaches and that they were getting sick because the electrical light bulb was on and they did not want to use it, they believed that some strange forces where happening and that they were going to die. So, to sell light bulbs they always had to have to put a label on it saying, "this is Edison light bulb, it is not inducing any headaches, no illness what so ever, it is just easy to be used". Same thing also happened to industrial manufacturing, when people lost their jobs, and did not wanted to have machines, and there were some riots because machines were taking peoples' jobs, so it happens all the time, and it is a similar problem now, people thinking that the machines are going to take the jobs away and that nothing good is going to happen. But that is not true. The truth is that we are improving the productivity and humans can work more on high level jobs. It is of course going to be painful to some of the people, but mostly it is improving. So, those are the main things.

So, talking a bit about the Industrie 4.0, because one of the problems is regarding SME's that they don't have enough capital to invest, so what do you consider to be the best approaches for government and public policies to actually help these small enterprises, because here in Portugal we have the same problem.

- The government helps, also here in Germany on creating funds like Industrie 4.0, meaning not only giving money to the companies, but also teaching them and encouraging them. It is not only developing the new machine, it is also the program that includes training of the people that will maybe lose their jobs. That's what government can do. The smaller

companies will embrace and accept new technologies, as I said in the beginning, only if it helps them, only if it improves the productivity, if it does not, it is not going to happen. And it should happen because new things, and if you think about the example about the smart coffee cup, are the things that you don't need and if you have to be honest enough and ask ourselves "does it help us?", "is it something that I really need?", "is it just a hype that people are talking about, so I have to do it?", "or is it really a need that is going to help me to be more competitive in the future?". So, for the Portuguese government I would recommend to also look at the German programs and platforms that we are working here, maybe on a smaller scale, but yes, the government must support the transformation, because if it does not, it will not happen to Portugal, it is the same fear we have here in Germany, if we don't do it now, and if we skip it now, we are going to lose the race and it may be too late.

And for this to happen quicker maybe the whole ecosystem needs to work together, like startups, SME's and universities. Do you think that this will increase the pace of adoption?

- I think so, in Germany, what is really strong here are the startups. Startups with great ideas and option to improve the innovation of the SME's. What we also have here in Germany is the strong networks of the institutes, working on applied researchers or developments that can easily be adopted in the industry. I don't know how this work in Portugal, if it is only universities, or if there are also institutes. Institutes are more connected to the Industry, to the market, and universities are more working on the base research. And yes, it can help, depends again on the programs and the flexibility of the researchers, the institutes and the universities to move faster forward. We also see some problems in administration, bureaucracy, not being fast, waiting for 20 years to accept the project and then you know that everything changes in the market, and so on. If it is accepted it must be lean, fast, dynamic. Otherwise it can make more problems than help.

Once again, thank you for your time and valuable insights.

Expert 6 Interview

Job Title: Professor/ Director Porto Design Factory

Interview date: 27th of October of 2017

Interview local: Non- applicable – Skype Interview

Interview length: Thirty-eight minutes

Good morning. First of all, thank you for your availability to share with me some information. I am doing my thesis on Industry 4.0 in Portugal and I would like to know your view on this topic in order to understand your perception and analyze the level of adoption of the Portuguese industrial sector. Therefore, I have a set of questions I would like to ask you.

- I'm not an Industry 4.0 expert, my angle of analysis is more focused on skills and people, although for what I do, I do need to know what Industry 4.0 is, the impact, technologies and everything.

It is also important to have several perspectives on the subject, hence also getting in touch with you. In any case, the first question would be to say what you think that Industry 4.0 is, even if it is not the more technical view.

- Alright, in my view, this idea of the 4th industrial revolution has a lot to do with the impact of digitization and digitization on a rather broad concept. From the digitalization of the processes not only of manufacturing, but also in retail, in all dimensions of the business environment. This impact has a lot to do with the growth of technologies or technological assumptions that have directly affected the technologies of production and distribution, as artificial intelligence or machine learning and that, in the end, ends up accentuating what is a

trend since the first industrial revolution, which is the progressive incorporation of technology and which has conflicted with the human resources and human resources technology that these companies have. That is, with the need of companies to improve their production, distribution and sales systems, with the need of companies to become more effective, faster. As well as with several changes in the consumption profile around the world, and which have had a particular impact on the idea of time-to-market, increasingly shorter, tighter, companies look in technology for the answers to these trends in the market, namely incorporating digital systems on top of physical systems and so here the dimension of cyber-physical, which is very important. Implementing and accelerating the implementation of robotics and electronics to perform functions that today are performed by more conventional machines or even by people and, therefore, the Industry 4.0 is this rapid acceleration of the pace of incorporation of technology and especially of digital media into the technologies of distribution, production and sales, which generate an obvious impact, I would say 360º. It is impossible not to have a holistic view of Industry 4.0 otherwise we do not understand the phenomenon, but it generates an impact that is overwhelming and perhaps, for that reason, it is considered an industrial revolution, because in fact the transformation is extremely big.

And how are you related to the subject? Because you are a university professor?

- I am a university professor and I am the coordinator of Porto Design Factory, which connects higher education and companies.

And you were also related with the creation of the Start Industry?

- Yes, Start Industry is a summer camp of entrepreneurship very focused on Industry 4.0, we were working entrepreneurial and innovation skills among people who attended summer university, but who had ideas of added value for the industrial sector, or for 4 or 5 industrial sectors, but very focused on 4.0 yes.

And there is another project that I coordinate, which will perhaps be more important for Industry 4.0, which is a project called Universities of the Future and which is funded by the European Commission, and which involves 13 partners across Europe. It is led by us, here in Porto Design Factory and aims precisely to generate a response from the point of view of education to have an impact on 4.0. And with focus, in the short and medium term, on how do we help companies to do the up-skilling and re-skilling of their current workers, so that they do not have to dismiss them, at a time where machines, robots, digitalization generates redundancy of functions. The World Economic Forum estimates that 7 million jobs will disappear from Europe in the coming years only because of the impact of digitization and cyber physics and redundancy of functions, therefore in the short-term re-skilling and up-skilling.

For two years we will design public education policies that will allow us to create new models of advanced training for workers, continuous improvement etc., we will create a joint postgraduate course between us, the University of Alto in Helsinki and the Polytechnic of Warsaw in Poland. A postgraduate program for digital change leaders inside companies. We believe that there is a group of people who can be the leaders of the digital transformation and simultaneously the leaders of the educational process of the workers of the companies and therefore we want to transform these leaders.

Then, on a second moment, in the medium and long term, how do we change and adjust the curricula of undergraduate and postgraduate courses in the context of higher education in order to respond more effectively to what the new needs in the labor market are. All this in a logic of policy recommendation for the European Union. I would say that the European Commission through the Erasmus + program and the knowledge aliases chose this project to be their roadmap for the university of the future in the context of the impact of Industry 4.0 on the labor market, so I also have this connection to the subject.

Yes, in fact it is quite important because it is really a necessity that exists at the moment. Speaking about the employees who work in these companies and that, if they do not adapt to this new environment, they could lose their jobs. What skills do these workers need and how can they adapt to this new reality?

- We have been trying to listen to the companies, for four years we have been doing this work, in Porto Design Factory, we have been trying to listen to the companies and try to perceive from the side of the companies what are the skills and we have come to some conclusions.

First of all, of course, technical and scientific skills will continue to be important, that is, we will continue to expect a mechanical engineer to know a great deal about mechanical engineering and we will continue to expect a programmer to know a lot about programming and a designer, a lot about design, etc. However we have realized that when companies seek to recruit a mechanical engineer or designer or programmer they do not want him to know just about mechanical engineering, but they also want him to have a set of competencies, which we call transversal competences, which allow them to have a different adaptability and learning capacity than the one that has been required up until now, we are talking about soft skills, almost emotional competences, managing projects, managing international projects, managing intercultural communication when teams are increasingly diverse in discipline, geography and diverse in culture. Knowing how to have the emotional intelligence necessary to manage a project, to manage a budget, to have a critical thinking process and to look at problems in a creative way. There is a set of transversal competencies, for example the World Economic Forum identifies 10 of these competencies as those that are fundamental in the context of Industry 4.0, but we can add another 10. What we are saying is that in a world of specialists we need to have some generalists who can establish connections, act as mediators, as facilitators, as enablers, but above all what the companies want in the 4.0 context are workers who have an

extraordinary ability to continue to learn continuously, and this means an adaptive capacity, an adjustment capacity, which until now was not so relevant and so important. The speed at which change happens requires that the thinking process of a worker of the future needs to be a rapid adaptation process of fast learning and therefore, it is important to work on this. The truth is, and now on the side of higher education, the truth is that we cannot qualify people for the fourth industrial revolution in the same way we did for the first industrial revolution and the problem is that higher education was first designed in the first industrial revolution and continues very similar this days. We, here at the Factory, are fortunate that we can be a laboratory of experiences from the point of view of teaching and learning and, in fact, everything we do is deeply radical compared to what is the normal context of higher education, but we are the exception, we are the bubble.

The truth is that there must be a monitoring and a transformation here, on the side of higher education, and then the whole education system needs to follow this trend. I can give you an example, Finland is currently experiencing the idea of the project base learning in basic education, that is, a new way of learning mathematics instead of having an expositive, theoretical process, we begin to learn mathematics in a real and practical context.

We are again appreciating the context of learning that happens when two children play in the street, when they contact with the nature, when they fall off the tree. In my time, when I fell from a swing I did not have a rubber surface that prevented me from hurting myself, but when I hurt myself, I learned, and this has disappeared a bit and now, there is a revival of some issues, but above all there is the idea of a teaching and learning process much more focused on the reality of development in co-creation with the companies themselves, so I think these will be the big challenges and it is what Industry 4.0 is most impacting on the point of view of the market.

It has been developed in the past few years, the idea of T shaped people, a T shaped person will be someone who has a vertical base background. There is the vertical bar of the T very solid, for example if I am a mechanical engineering, I have a strong background of mechanical engineering, but then above this vertical education, I have transversal horizontal skills, the horizontal bar of a T that allows me to have a flexibility capability, being able to adapt, to be able to adjust to contexts that are in constant change. After this theoretical formulation of T shaped people, we are already working on π shaped people, that is, not only a very strong education, we already need two, maybe one in the engineering area and one in the business area, or one in design and one in the field of engineering or psychology, that is, multidisciplinary is already important even for the best engineer or the best designer or the best musician in the world. These are concepts that we have been working on.

Makes sense. And yes, the education system needs to be transformed, because at the moment, what we have is a secondary education already very focused on what one wants to do in the future and on the access to higher education, it would have to be all rethought. And this program is already in contact with companies? And are they more industrial or from all sectors?

- We are transversal, I give you an example, here in Porto Design Factory, this year, everything we do here, just for you to have a notion, all the programs we have developed have 5 common characteristics and are only those that are common all the rest is different.

All the work is done in a team, all the teams are interdisciplinary, all the interdisciplinary teams are also international, half the team is here in Oporto and half is somewhere in the world in a partner university, we always work for impact and this means that we develop real solutions for real problems of real people, typically with companies, but also with NGOs and with public entities. And we are human centered, we put the end user, the person at the center of our whole process, which means that whatever we do, we do together with companies. This year we are

working with about twenty companies, we have mega multinationals like Nokia or like Phylip Morris, like IKEA, we have mass manufacturing dimensions like the IKEA industry, we have SMEs, we have startups. In the context of the universities of the future we seek to have a distribution of dimensions and sectors, we work a lot with retail for example, which is an industry of great importance and where the impact of 4.0 is brutal, although the studies of 4.0 are very focused on manufacturing. Therefore, in the University of the Future we have IKEA industry, mass manufacturing, factory floor, volume production, 1500 workers in each factory, things like this. Then, we have a retail company that is Wilson and Brown, a polish company, and then, we have a technology startup in Finland, because we want to hear from them all. The companies have different needs according to their geographies, their dimensions, their areas of operation and, therefore, we work in a very transversal way. We are working with Ford and we are working with a two-person startup and we work the same way with both of them, so we are very cross-cutting in size, business area, technology, business model, we like to say that we are agnostic about it all.

This is very interesting, I will also explore a little bit more. Regarding older workers within the company, how can they adapt and what can the company do to avoid dismissal?

- Exactly, this is an issue that we want to investigate and work on and generate concrete responses with public policy recommendations for the European Commission over the next two years. I would say that, of course, there has to be, in the first place, the perception on the side of the worker that has to make this process of adaptation and there must be a paradigm shift here, workers cannot, for example, the idea that exists that the worker is able to wait for the employer to solve all their problems for them, I think that is outdated. And this is a matter of mindset, so first of all change the mindset. We need an entrepreneurship mindset, that is, we can be entrepreneurs being a machine operator in a large factory, this has a lot to do with proactivity, not waiting for things to solve themselves, not having risk aversion, this is very

important, so first of all a change of attitude to a more entrepreneurial attitude, not entrepreneurial in the sense of let us all create our startup, but entrepreneurial in the sense of lets be active, proactive, let's take care of our company because it is ours too.

Secondly, get out of this comfort zone and seek to learn, develop a learning process on topics that can impact your business and your professional life. And this does not require the company to design a training program, it is not necessary for the university to create a postgraduate program, this information is online, information is available, the Internet exist also for this. It is very relevant that people have a different attitude towards the knowledge that is at its disposal, nevertheless, one of the objectives that we have is precisely to compile and organize a set of knowledge in several multimedia tools, very adapted to the present, to the way people consume information on the Internet, something that will be called Virtual Design Factory and that will precisely seek to make available to anyone this possibility of learning. But today there are many very structured programs, the coursera, there is so much available, it is necessary that the worker has this attitude. And if the worker does not have that attitude we then have a basic problem.

On the firm's side, companies have to learn that as important as training their employees to understand how to work with the new machine, is to provide advanced training to their workers so that they can develop transversal skills and that opens up the companies' spectrum of knowledge, that is to say that they can do what we called the up-skilling, I'll know more in my area, and the re-skilling, I'll know more about other areas. And I've been an electronic engineer all my life and I've worked on programming and suddenly I'm interested in something else and I'm going to try to develop skills in something else, because my company will need it more than what I did before. Companies can have this notion of advanced training and continuous improvement programs more open than ever before. Training programs are typically very focused on "an update was made to the billing software, let's all have training to know how

to work with it" and it cannot be just that, you have to go beyond that. So, I would say it is this, mindset and, on the other hand, companies realizing that the training programs have to be more ambitious, more comprehensive and have to qualify their workers for a professional progression that is done towards the up-skilling and re-skilling.

And taking into account your experience, what are the main factors that influence Portuguese companies to move to an Industry 4.0? We know that we have a human resource problem, but what other factors are there?

- Well, there are two ways of analyzing this question, on the proactive side and on the reactive side. But critical factors, yes, human resources, clearly. A fuller and more holistic understanding of what technology allows, in particular in SMEs, 4.0 still continues to be seen as the ultimate machine model, but the truth is that the transformation is deeper and will generate the need to revise models of production, distribution and sale.

Of course, the capital factor is important, the digital transformation although it is cheaper than any other technological transformation it has costs. Therefore, a holistic understanding of what is the impact of 4.0 on all dimensions of the business, the company and the understanding that 4.0 is not doing digitally what was already done physically. This reminds me of what happened ten or twelve years ago, when the first ideas of the Paper free work environment began to emerge, lets digitize the workflow and what was done? The bureaucracy had 10 validation points on paper, and simply went on to have 10 validation points in digital, that is, documents were scanned. 4.0 is not scanning, it's not scanning processes, it's redesigning processes, and that's a critical factor.

Anyone who does not understand that the impact of 4.0 presupposes a profound redesign of the production, distribution, and sales models is not understanding the 4.0 and, therefore, there must also be a dimension of requalification of the owners themselves, and CEO's and administrators of the business class. The capital factor as I said, and then, there is also a

regulatory and legislative factor, we cannot base an industrial revolution on the idea that the government will subsidize part or all of the costs of adaptation, but we cannot leverage an industrial revolution with regulatory and legislative constraints of the time of the first industrial revolution. And here we touch again, in this legislative and regulatory dimension, the human resources dimension, and it has to do with labor legislation. The Portuguese labor legislation has undergone some interesting progress, but I think it is still not adjusted, I would say it is not adjusted to the current reality, much less the reality that 4.0 will generalize. If we are to say that companies increasingly need flexible and adaptable human resources, we cannot have a labor law that does not encourage or hinder labor flexibility. And be aware that flexibility is not about flexibility from the point of view of the level of remuneration, I am not even talking about the term contract or the contract without term, I am talking about labor mobility, both intra-firm and between companies, we need to go back to something that has been much discussed as the Scandinavian model of flexicurity, but we need legislation that allows for more flexible, more flexible mobility, progression and the labor market, and simpler to a certain extent, I'm not saying let's facilitate the dismissals, but let's facilitate the movement of people between companies for example, which is a little bit different. So, I would say that we are again talking about the mindset, also on the part of business owners, what to do with human resources, the holistic view that 4.0 presupposes a profound transformation and not an incremental change and a legislative and regulatory environment adequate to the demands and the needs of 4.0.

Then does it make sense that in the future there are workers who are not associated with a specific company, but rather with several companies?

- Absolutely, and increasingly remotely because I get to work from home because the systems are digital and if tomorrow I want to be working from Singapore, I go there and there is even a space of co-work that welcomes me, and I become a digital nomad.

All these dimensions are very relevant, I would say that the future of the labor market passes through this notion of work flexibility and this also has a generational impact, we are already talking about the new generation and the way they face the labor market, much more mission driven than salary driven, much more looking for life experience, but their lives are also much facilitated with remote and collaborative work becoming more a reality and technology 4.0 will further facilitate and stimulate this type of dimensions, so we are talking about not looking at the labor market in the rigid form of contracts, functional contents, departmental hierarchies, 4.0 goes much further and will be very different from that. It's going to be no, it's being.

I know that in Portugal the government also has a great impact.

- Yes, but also all over Europe. The European model is a model very dependent on the government for many things and, then, when it is the business environment that has initiative the governments difficults, which is another dimension, but if we analyze, just as we have the Industry 4.0 strategy for Portugal, practically all the countries of the European Union have similar strategies and are articulating them which is very interesting.

What do you consider to be the level of adoption of industry 4.0 in Portugal?

- I think we are at 25% and I can explain why, we have a set of leaders of this digital transformation, typically big companies, manufacturing companies, multinationals. Because AutoEuropa is 4.0 long ago, Continental Mabor, almost all Bosch units, the unit of the IKEA industry, that is, all these big players are making that transformation and are already leading. On the other hand, we have an increasingly vibrant ecosystem from the point of view of startups, who are living in this digital ecosystem and are the agents of transformation because they are developing products for this 4.0. So, what is missing here? That is why I consider that we are only at 25% and this is a very empirical thing, because I do not have a fact that can justify this, it is a very empirical and little structured thing. It is because the large percentage of the

Portuguese business environment is in SME's, and within SME's, is in micro and family, and those have made an extraordinary effort of development and innovation, but continue to have a greater difficulty, because of its size, lack of scale effect, because of several things, lack of capital, lack of capacity to withstand the investment in qualified human resources that can think and direct this transformation. The return is medium to long term and SMEs are always very focused in the short term, they are not yet doing the transition, they still think that 4.0 is buying the new model of the machine and what will happen? It will be the market to tell them that they are going to have to evolve and this is what has been these 30 years of evolution in our business economy of SME's, that is generally more reactive than proactive, even success cases such as footwear. Footwear is today an industry that I would say is more innovative, it is one of the most innovative industries in our country, but the truth is that it had to go through a brutal structural crisis in the late 80's to reposition itself. Today they are leaders and they are proactive, but they did it in a reactive way. The same with the textile, I would say that the textile is today with an energy and an effervescence that we had not seen for a long time, but we had to pass the nightmare of the relocation of the production to China and only now we are recovering. Metalworking, which is the sector that exports the most in Portugal, has done this transition mostly because of the requirements of large industrial units and the sector of machine production, for example.

The truth is that we need a more proactive business environment and I would say that the slow pace of adoption of the assumptions and technologies that characterize 4.0 is something that is structural in our country and that I have some difficulty in understanding how it will be exceeded.

I think the national strategy has to, and I'm not part of the industry 4,0 committee, but I know almost everyone who is, and we've talked a lot to figure out how we're going to get SME's and no, it's not throwing money at SME's, with Portugal 2020 and with Compete. And of

course, funding is extremely important, but the strategy has to be more structural rather than governmental conjuncture, and we are not the best planners in the world. The steps that have been taken by this government, especially at the beginning of its mandate with João Vasconcelos, have been extraordinarily important, it is necessary to continue, and it is necessary to strengthen, and it is necessary to operationalize, to leave the strategy and to take action.

And in terms of SMEs, do you think they already have knowledge about Industry 4.0 or is it something that companies look at as something that brings risk and that is why they choose not to adopt?

- I think there is a great deal of pure and hard ignorance and another large portion of misinformation and misperception of what the phenomenon is. So, we are doing a series of workshops, called innovation one-o-one, that will start now, what we are doing with SME's, precisely to spread the word a bit and guarantee this reinforcement of information that I think still needs to be done.

Last question, and a question a bit of futurology, if you had to estimate, in number of years, how long it will take Portugal to adopt this new reality, what would you say?

- A complicated question, I have to balance between my optimism of working closely with new generations and see fantastic things happening to these people that will reach the labor market, and my pessimism of what has been a story of little proactivity of our economy. I would say that we are always going to be behind, what matters here is to reduce the delay gap in relation to the economies that are adopting these processes more quickly, but we have a good 10 years ahead until this is the standard.

Once again, thank you for your time and valuable insights.

Expert 7 Interview

Job Title: Professor

Interview date: 31th of October of 2017

Interview local: Non- applicable – Skype Interview

Interview length: thirty-five minutes

Good afternoon. First of all, thank you for your availability to share with me some information. I am doing my thesis on Industry 4.0 in Portugal and I would like to know your view on this topic in order to understand your perception and analyze the level of adoption of the Portuguese industrial sector. Therefore, I have a set of questions I would like to ask you.

What is Industry 4.0?

- Well, Industry 4.0 has mainly to do with the application of a set of technologies that have consolidated in the last 10 years to the industrial production. One of the most visible parts of these technologies is the Internet of Things and then comes that reference to IoT or Industrial Internet of Things. And that means that we can have industrial production systems with capabilities that have not been possible until now, because this allows us to have a real-time and real-time knowledge of what is happening in a factory and with a lot of consequences. In the vertical view, therefore, it has to do with the integration of the equipment from the factory floor to the management systems of the company. Therefore, factory floor systems can directly receive manufacturing orders from a management system and coordinate all production, as this production and management co-ordination system receives information coming down from the availability of the various machines and you can automatically manage how best to route those production orders. So, this is called vertical integration. And there is also the part of horizontal integration that I can get between the two ends of a production chain to make the automatic connection between the various actors and ensure that the tuning points of the chain are aware

of what is going to happen to them and when they are waiting for the products arrive. But other concepts begin to emerge here, one of them is the digital twins, that is, the digital replica of the entire production system where decisions are made. For example, when we travel today and use GPS, what we do is make decisions about the best path, not the physical reality, but it is a virtual replica of that reality, which today resembles what happens with Industry 4.0 systems, online status information. If I am on google to choose the path I have the updated state and if there is any route with slow traffic ahead, it may be created and suggested detours. Therefore, this concept of digital twin turns out to be something that people today already use in another context. This is let's say the technical part of the question.

Another aspect that I have always called attention to is that it is necessary not to forget that this name of Industry 4.0 is the strategy that informs that is generally taken as industry 4.0 and in which the description that I have just gave you fits, it is a strategic program of the German government. And that's an important point because you just have to pick up the 2015 or 2014 document that gave rise to it all from a study group from the German Ministry of Industry and other entities that clearly states that Industrie 4.0 is a program done to take advantage of the competitive advantages of the German industry, especially at the level of embedded systems and industrial technologies. So, this is an approach that is made to privilege those who have strength in these areas and Germany has. There is Bosch, you just have to think of two players in these areas, that is to say Bosch, which is the world's largest manufacturer of embedded systems to account for what it produces for cars. The electronics cars nowadays, if not Bosch, have Bosch licenses. And regarding the industry, Siemens. The major part of Europe's top industrial production systems is from Siemens and there is the clear objective of bringing the two together and that is an important aspect because from a strategic point of view, if we embark on an action, we have to be clear about what our advantages are and what our strengths are and

what our weaknesses are here. The Germans did their SWOT analysis and chose this path. Now, we have to understand what the Industry 4.0 is and select the best path.

And what technologies do you consider crucial to the implementation of Industry 4.0?

- On one side is what is called the cyber-physical production systems and there we have some capacity for development, here in Portugal we have knowledge and capacity. Above all, we have a situation related to what I said before of the industrial environment. We have an industrial fabric which is essentially composed of small and medium-sized industrial enterprises, I can then give you these numbers, the employment number generated by the industrial sector is close to 90%, in Germany is 60%. And what does that mean? It means that there is a very developed structure at the level of big companies where it is much easier to manage transformation programs, because if Bosch or Volkswagen decide to go through a certain production system, there is a set of companies that follow them only because the big players decided this. The 1st, 2nd, 3rd line suppliers of a factory, such as AutoEuropa, for example, the only thing they can do is follow the standards that their customer says they have to follow. When there is an industrial environment with great actors, such as these, there is a condition for the implementation of large projects guided by these actors. Here in Portugal we have a very different situation because of the large number of small and medium-sized enterprises. What we have are small and medium-sized enterprises that have little investment capacity and less capacity to invest in large-scale programs. What does this mean? It means that for Portugal we have to take a different approach aimed at small and medium-sized industries and the things that have been talked about a lot in recent times is that “retrofitting” can be a solution, that is, arranging solutions that, relying on part of machines which are already installed and that do not need replacement. That it can be created mechanisms of support for intelligent production, so to say, as much as possible in what already exists and not by alteration.

You spoke of some factors that really affect the implementation of Industry 4.0 in Portugal, such as small and medium-sized enterprises, capital, etc. What other factors do you consider important and that influence the implementation of this new reality?

- Now from an advantaged, the situation that we have to have a major emergency of, we actually have some SMEs from the industrial side and this creates difficulty in entering these programs. On the other hand, we also have a large number of SMEs on the side of solution providers, and in particular a great activity at Startups level, some of them successful in this area such as ProdSmart. These companies are much more agile than other larger companies and this allows them to respond more quickly to new requests and be able to develop new solutions, so that is also a positive factor.

And you also related to the subject at the academic level or is it more at the professional level?

- I am related at the academic level, in particular I have been working on a program called ProduTech. ProduTech ends up being the collective action that in recent years has developed actions closer to what is this concept of Industry 4.0, even before this hype appeared in the last two years. Talking about Industry 4.0 is a very new thing. I instead of talking about Industry 4.0, I prefer to talk about the digitization of the productive processes, it is to apply to the productive processes this intelligence and there are also other related things like the so-called additive manufacturing, which in Portugal for a few years was called rapid prototyping, and this has to do with the Internet of Things. One thing is I have the information spread, and another thing is I have a 3D printing machine that makes us a piece, the common point between these two things is digital information, that is, it is on a server somewhere in the form of bits and bytes information about the production process, about the construction of the piece and then things cross and the great advantages of the process emerge.

And another advantage that I remembered, there is also, I have already spoken on the part of the Industry, I have also talked about the offer of solutions like ProdSmart and then there are also two or three players in the set of dynamic companies, also all of them generally SMEs of developing solutions for factories, that is, not being as advanced as Prodsmart to develop its own product, but are those who develop and are on the ground to develop and assemble solutions for an assembly line, for example and that have capacity to integrate new solutions and I am aware of some of these cases that are being used, because thanks to the flexibility they offer, they are being used by some big players to test solutions related to this topic of Industry 4.0. This means that with the support of a large multinational they may be rehearsing solutions that they can then apply in other contexts.

And University of Aveiro is also closely linked to companies and is working together on other projects of Industry 4.0, for example with Bosch?

- Yes, the project we have with Bosch is more related with the Internet of Things, than Industry 4.0 itself because the project has to do with the development of intelligent home solutions, but in the background what differs is the field of application, because the technologies that are the basis of one and the other are exactly the same. There is only a change of context here that while we are talking about Industry 4.0 we are talking about solutions to be applied in the context of factories and production lines, when we are talking about smart houses we are talking about exactly the same kind of situations, but in the context of the equipment that we have at home, that is, instead of knowing in detail what is going on in a production line, I know in detail what is happening in my house with things connected to heating, with the refrigerator, for example they are now seeking to interconnect the various things. Having a robot that walks alone to clean the house and that uses the information about dim lights and lights on to find out which are the most used house places and organize the cleaning missions that it does based on that information.

Our intervention at Industry 4.0 level is more linked to ProduTech's other mobilizing project, where we, as an electronics department, have more intervention at the level of the signal acquisition part and the development of such systems that are capable of absorbing information that is available on the factory floor and systems of storage and processing of information, at Big Data level, etc.

Regarding technology, because there is some confusion in the literature review. Can we consider cyber-physical systems to be part of the Internet of Things?

Yes. The cyber-physical system, what the name means is that it has a digital component, the cyber part, that interacts with the physical part. And it is not like a mobile phone or a computer in which there is not properly an interaction with the physical environment, the interaction with the PC turns out to be writing text and receiving image and audio, it can be movies, it can be things that I read. When we are talking about cyber-physical systems we are talking about computer systems in which there is interaction with the environment, where either these systems receive information whether it is able to act on what goes around, heat, cool, connect motors, etc. So, the CPS's turn out to be the frontier with the real world of the Internet of Things. After the Internet turns out to be, on those systems a network of data communication, or rather a system that has a network of data communication and has, and if there is no information organization component, when the information grows they no longer have the capacity to deal with it.

Alright, because there really is a lot of confusion still about these two concepts. Speaking again about the Portuguese situation. We know that Portugal is heavily influenced by the government and public policy. What do you consider to be the best public policies to help in the transition and the level of adoption of industry 4.0 in Portugal?

The public program that is now, personally and also for the reasons I have already said, I think it too focused on big companies and too much for companies that are not Portuguese.

There are working groups with smaller companies, Prodsmart, Followyourinspiration, Beeverycreative, these are Portuguese companies that are in this working group, but there is a very large component related to the intervention of companies that are not Portuguese and, as I said there are a lot of strategic issues that are important because if we do not care about those issues what will happen is that our effort will be taken by others and will serve more to others than to ourselves. Therefore, something that is important to ensure is that this, all actions that are taken are reflected in improvements in the competitiveness of national companies and not contributing with solutions to improve non-national companies operating in Portugal and this is an essential aspect in the policies linked to industry 4.0, which is to ensure that I can defend that part. And we have examples, has to do with this issue of small and medium enterprises, there is an analogy that happened to the telephone industry: here in Aveiro there is the old PT innovation, now called Altice Labs. Altice is a multinational group and PT innovation was bought by Altice and had enough credit to be the current headquarters of innovation and development for Altice, so we are talking about a French group that bought Portugal Telecom and decided that a team from Portugal Telecom research center would be its world research center. And where does this PT research come from? It comes from work that was done around 1950 because it was necessary to automate the telephone network in Portugal and one of the difficulties was the rural areas. There had to be a telephone wire every 2 kms and there were no solutions to this situation. We have a country with a large population dispersion and the CTT, that at the time had the telephones, created this study group to begin to work on the development of solutions and they began to do automation of the telephone network. This lead to the rise of technical skills and development of new solutions, for example prepaid card, actually Portugal was the first country in Europe to have a prepaid card system because it involved solving problems that no other operator in Europe had managed to solve. So, the analogy to this situation is which? In the case of automatic computing, it was possible to develop specific

solutions aimed at our national reality, in addition to immediately solving the problems we had to create skills and knowledge that were then continued. This was also achieved on account of a great link between university and industry. What I think it is necessary is to create identical situations now talking about the part of industrial production.

Yes, it makes sense that there is that collaboration. Given your experience, what do you think is the level of adoption of Industry 4.0 in Portugal at the moment?

- I cannot tell you, I know that according to each sector there are very different realities. I do not know if you have already spoken with the Molds and Tooling cluster. This is a sector where for many years the technologies associated with Industry 4.0 have been used for a long time and that is where Portugal gained its reputation in the mold industry. And for example, this digitization and the dominance that these companies managed to have at a very early stage in the digitization processes allowed for much more flexible solutions with a much more efficient response to the customer than many other companies that were competing with them at the time. And Dr. Rui Tocha who is the director of the Tooling cluster, he witness the entire process. So, these are companies where this process is far more advanced. Other production sectors are still working with single machines with sheets of paper where the production orders are, or the production is first written on a sheet of paper and then if someone has time passes to computer in an Excel, that is with the absence of integrated production management systems, if they have a dashboard comes with days of delay and information failures. So, there are situations that go from one end to the other. The tooling will be one of the examples of already using large scale in this type of solutions, the footwear as well. In the case of the digitization, we have a company that is the CEI in São João da Madeira which started by making stone cutting machines and then was challenged by the footwear industry to use the same technology to make skin cut and what they have is this system of having several pieces of skin to cut, the cutting machine has a camera which is viewing the part being cut, identifies the defective parts,

eliminates them and in the good part of the skin places the various parts to be cut in a manner to make better use of the space of that skin. This is an example, although it is not widely spoken in Industry 4.0, but has to do with the processes of digitization of production processes. That is, I first work the digital part, prepare my work as much as possible and then, when I move forward, make sure that I have already explored the various alternatives and the one I am choosing is the most appropriate.

The last question, and a bit of futurology, but if you had to estimate in number of years, how many years do you think Portugal will take until adopting Industry 4.0 in totality?

- That is not easy, but if you ask me for a number, it depends on what you understand, because it will never be fully implemented, but in an expressive way I would say between 5 and 8 years.

Once again, thank you for your time and valuable insights.

Expert 8 Interview

Job Title: Professor

Interview date: 3rd of November of 2017

Interview local: Nova SBE

Interview length: Thirty minutes

Good afternoon. First of all, thank you for your availability to share with me some information. I am doing my thesis on Industry 4.0 in Portugal and I would like to know your view on this topic. Therefore, I have a set of questions I would like to ask you.

I would like to start by understanding how you came in contact with the topic of Industry 4.0.

- Right, it was more through some colleagues from the university where I worked, at the University of Birmingham. I have some colleagues who are dedicated to the study, including

Professor Lisa, they do a lot of work in this area and even have great research banks, between several companies and several countries and went a little there. Then by interest I found the subject very interesting and I ended up doing a job or another with them also within this topic. Not being specifically my central research topic, but only by tangent, because my area of expertise is more strategic mergers, for example partnerships, and that area. So, one of the projects in which I got involved, they asked for my collaboration to work on this perspective of partnerships, in addition strategic partnerships between production companies, manufacturing firms, and service companies, or product service innovation, partnerships between producers and services, and it was precisely in this area that I ended up collaborating with them.

So, does it make sense for a faster, more efficient transition to Industry 4.0 to have such collaboration across multiple players?

- I think that in almost every type of growth, partnerships, I would not say always but it is almost always a factor of acceleration or it helps to achieve the same or better results but more quickly too and sometimes it is inevitable as companies not always have the capacity, after diversifying and specializing in the part of complementary services and as such, it becomes inevitable these partnerships. And are essential for competitiveness, for countries, even for the European Union, which turns out to be a partnership between countries.

But the partnerships we are seeing in Portugal are more connected to the engineering part, in the management part, but maybe in the future will start to exist, but speaking in partnerships of universities, they are still not investing much in this management area.

- From my Birmingham experience, in fact they are already being developed there.

But do they work together? Students and companies? Or is it more in the research part?

- It's more research, it's almost all done by staff.

Can we focus on the UK reality, because they are also investing heavily in Industry 4.0 as an advantage in relation to Brexit? What factors exist in this reality?

- Yes, I think there are some factors that can be replicated in this reality of Portugal and other European countries as well, because the agenda itself is not only a national agenda but a European one, that is, there is a great will, recognition of the need for development of the industrial sector, some works have begun to devote some attention to reshoring, revitalizing the manufacturing industry and in which Europe is impossible to compete on only low costs such as the case of China and other countries that have competitive advantages in terms of raw material and labor costs. In any case not only Europe but now the United States, recognizes that the presence of a manufacturing sector is still important, but the only way to compete is through greater differentiation. Also, innovation, which involves the introduction of technologies, therefore also services linked to technologies, which help companies to be differentiated also through complementarity, called product service innovation. It is therefore the only hope that Europe has to recover a certain revitalization of this sector and of being able to compete with a different offer in the offer of advantages that other countries like China have, so I think that Portugal will not escape the same logic. And in fact, from what I know, I recently had contact with a company from the North that manufactures, so there is a certain type of product that they produce through vertical integration upstream, but by partnership, that is, they do not diversify total in house, but they resort to a strategic partner, I say strategic because it even has equity, equity alliance, with a supplier. So, they produce this type of materials and so on, and in fact their added value is not only in the production of the materials, but also in the technology that is complementary to the product, that is afterwards in the sale of the product, and they already sell in 50 countries, even in The United States, the sale of the product that has quality without doubt, is produced in Portugal with great quality, but then there are services allied to the technology such as internets, intranets and apps, etc., which are the sellers themselves they end up having to use services that go in complementarity to the product they are producing and this

gives them a huge competitive advantage and by the looks of it, it is very well received out there and has been having a huge exponential growth. So, in Portugal it certainly also applies.

And really, this aspect of partnerships makes perfect sense in Portugal, since we have a lot of smaller companies with less capital.

- In this case, I was talking about a partnership with its manufacturer, producer, supplier, but they can also join in the entry of new markets. They can also create partnerships with possible companies in the countries. And in the case of the United States, I will not mention the company, it was precisely that, they have someone who makes the sales, but given the digital and technological component allied to the product itself, there is a transmission of knowledge, know-how and technology that leaves them somewhat vulnerable and as such they were just talking about the possibility of creating a closer relationship, not only distribution, that is arm's length transactional relationship, but a closer relationship with the partnership. And they were discussing the various types of partnership, there have the possibilities of franchise, of joint venture, there are various types of closer relations. To have a relationship with a little more control than a partner, in order to protect the know-how, the technology, otherwise they become more vulnerable and there is this component of product service innovation, the combination of the product and the technological service, and they could lose competitiveness if another company does something similar, but as they have this combination of product and service, they have a huge advantage.

Yes, and now is so difficult to protect technological inventions so it makes sense that such partnership exists. And do you think that Industry 4.0 is a hype, as they call it, or is it something that really makes sense to happen and is happening?

- I think for the reasons I have already mentioned that it makes perfect sense if one wants to revitalize the industry. It makes perfect sense and is in fact a possibility, now the question of whether is going to become a hype or not, I would not say that it may not be, and that it might

lose its glow and the interest, but if that happens I do not know if it will be because it does not work, or it did not work because other countries, for example China end up getting in there. That is the European countries that are trying to differentiate and stand out, if China realizes the advantage, it can quickly invest and then dissipate the competitive advantages of other countries. Therefore, it is questionable and there is no doubt that Chinese and Indian companies, for example, have technologically grown immensely and very quickly, so they also have the capability and resources to implement it.

China has grown a lot and is investing heavily in Industry 4.0. And in more governmental terms, because we know that in European countries, the government has a great influence. What can government do to influence business adoption?

- For example, technological centers, clusters, links with institutions such as universities, promoting the development of research programs that bring companies from the business sector and the research sector into a communication and partnership once again. I think that this role of the government is in approaching this type of agents in the various sectors and can be important and fundamental. I think there has been a desire for it, even the European Union itself has invested in projects and demonstrates the political motivation that exists and has already realized that there can be hte salvation there, with all the problems in Europe. It can be this dynamizing role, of coming closer, of creating opportunities, of creating bridges, I think this is the role that the government has to play.

So, the government should maybe focus more in the collaboration side, maybe even more than in just giving subsidies?

- Facilitate yes, not only capital, but to create and facilitate relations. To have a dynamic role, let's say.

And do startups also end up having an important role again as a facilitator and partner?

- Yes, precisely.

Because they have the technological and innovation part and can join.

- Exactly, they can join and collaborate.

And what kind of partnerships do you normally have here?

- So, there are several types of partnerships, here I talked about a concentric partnership, that is, it is not horizontal between competitors, which is also important especially in small and medium-sized companies, the concept that one can collaborate with competitors, with competitors, is what is called coopetition, collaboration and competition, the two things, therefore these are possible and are the horizontal ones.

Also with direct suppliers, etc., such are vertical partnerships with other factors. The concentric ones are lateral, that is, there are companies that may not be direct buyers or suppliers, but that are in some way related and the basis of commonality will be, for example, a technological input, synergies, complementarities or else an output in the customer base.

Now, regarding legal form there are joint ventures, which confer certain advantages and disadvantages like all, franchising, licensing, which is more used with technology, know-how, patents, etc., so it is good to protect that aspect. But then, when I talk about government or other public institutions, consortia can also be formed, in the medium term, so there are lots of them, it's a big world and it's a very specific world and sometimes the question that you ask is important because the objective to a partnership may be timely and relevant, but the form of partnership can create problems or facilitate the relationship. And sometimes, when you talk about partnerships, people generalize, but each has its own specificity. For example, in the conversation I had recently with the Portuguese company, it had a lot to do with the kind of partnership that would make more sense.

And that coopetition partnership, what are the advantages? Is it more about sharing knowledge?

- Not necessarily, it can be knowledge sharing, it can be market sharing too, that is, when there are competitors that have a greater presence in a sector or a market and that can facilitate and create advantages to both, but usually it is the complementarity, synergies, normally are the main reasons for such partnerships. However, and also in terms of geographical complementarity, product, knowledge, technology.

And is it something that companies accept well? I'm thinking about the Portuguese reality and that should be more complicated.

- Yes, it is. For example, in the wine sector, one of the problems that I, not being an expert, I think exists, as when I was in England people have raised some questions about "why is Portuguese wine not so present here", since it is good and price relation / quality is the best. And it seems that one of the main obstacles was precisely the fact that the companies are very fragmented, because most are very small producers, everything is divided, everyone does their thing and then it is difficult to be able to guarantee consistency in quantity and quality throughout of x years, and the fact that everything is so fragmented makes it difficult. But cooperatives are a good example of trying to create agencies and platforms for competitors to realize that there are some kind of advantages in cooperating.

In Portugal, as the business sector is mostly small and medium enterprises.

- Yes, for these companies with less resources, cooperation is necessary to overcome barriers.

And there are also many companies that also have no brand of their own, end up supplying to Germany and other countries and end up not being able to define margins and are always conditioned by others. Does it make sense for Portuguese companies to start trying to create their own brand, even if they are companies that only manufacture parts?

- This company that I mentioned is already doing this, has been creating its own brand and it is becoming a known brand. In fact, one of the problems of collaboration with the United States was, first of all, knowledge, to ensure that it only passes enough knowledge and not too much, but the other is also the brand building, because is necessary to preserve it, knowing how the other person is going to work, that is to say there is a whole culture behind a brand that partners must understand and know how to contribute and preserve and when there is no partnership, the other "partner" makes their decisions and goes about doing things their own way. But branding is something that is possible and has happened.

Once again, thank you for your time and valuable insights.

Expert 9 Interview

Job Title: Engineer

Interview date: 4th of November of 2017

Interview local: Non- applicable – Skype Interview

Interview length: Thirty minutes

Good morning. First of all, thank you for your availability to share with me some information. I am doing my thesis on Industry 4.0 in Portugal and I would like to know your view on this topic in order to understand your perception and analyze the level of adoption of the Portuguese industrial sector. Therefore, I have a set of questions I would like to ask you.

What is Industry 4.0?

- Industry 4.0 is considered the "4th Industrial Revolution". It is based on the use of technologies (many already existent) of automation, collaborative robotics, artificial intelligence, cloud computing and IoT (Internet of Things), among others.

And how are you related with Industry 4.0?

- I got interested because of my Master's degree in Production Engineering, at the Setúbal Higher School of Technology (Polytechnic Institute of Setúbal), through some Curricular Units and Seminars / Lectures on the subject.

In your opinion which technologies are crucial to implement Industry 4.0?

- The perception of Industry 4.0 encompasses all these concepts, Internet of Things, Cyber Physical Systems, Big data, cloud computing, Artificial Intelligence, Robots, 3D printing, others. However, I think that Artificial Intelligence and Robotics will be the most crucial.

And in terms of challenges, what do you consider that are the biggest challenges for companies to transition to Industry 4.0 in Portugal?

- The main factors, in my opinion, will have to do with the investment needed and training/qualification of employees, which will also require investment. The Portuguese business environment consists essentially of SMEs, and we must also mention the context of crisis from which we are gradually emerging.

Which companies/industry sectors are the most affected by Industry 4.0?

- The sectors most positively affected will most likely be the large industries in the production sector: automotive, electronics, aeronautics, chemistry or even metal-mechanics.

What could be the "new" role for the remaining human resources in Smart Factories? What skills will they need?

- In a so-called "smart" factory, employees will most likely need skills related to automation, robotics, and information technology in general.

What do you think will be the main impacts of not adopting Industry 4.0 technologies?

- The non-adoption of these technologies will certainly have a negative impact on Portugal's competitiveness in the European and international context.

In your opinion, what is the level of the adoption of Industry 4.0 in Portugal? If we had to put it like in percentage from 0 to 100?

- 1%. Because the Portuguese business environment consists essentially of SMEs.

If you had to estimate, how many years do you think it will take Portugal to have fully adopted Industry 4.0?

- Not in less than 10 years' time.

How can public/governmental policies influence the level of adoption of Industry 4.0 in Portugal?

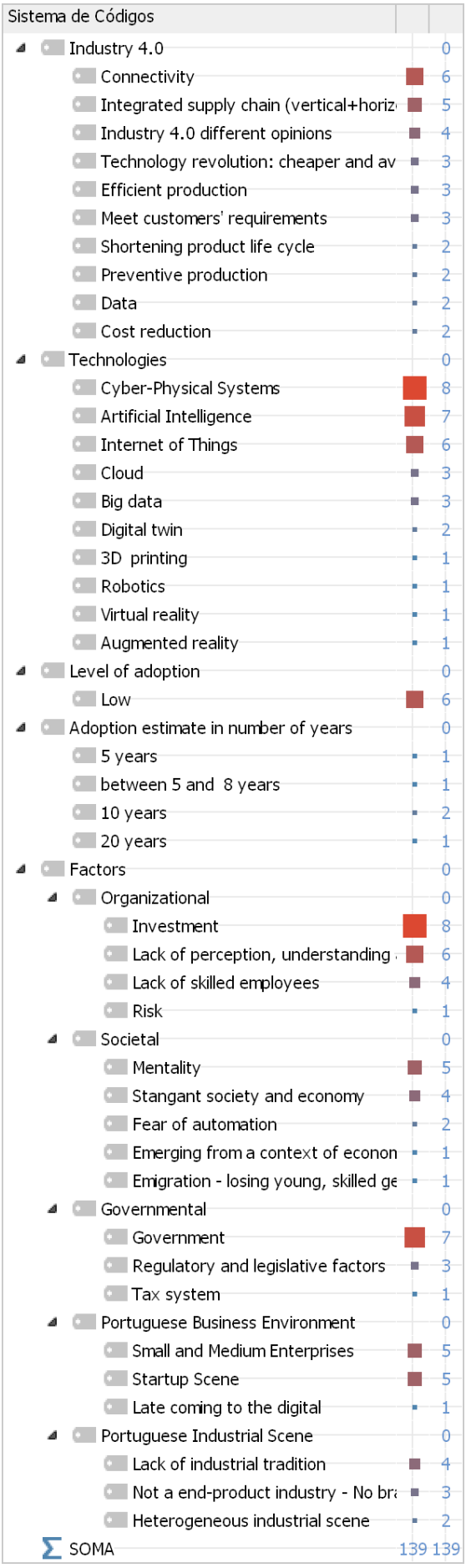
- There are already governmental initiatives within the scope of Industry 4.0 and its implementation (i4.0), in particular under the Portugal 2020 program (with European structural funds), I think these programs can positively influence the adoption rates because they bring attention to the topic and some of the programs also give incentives to companies to invest.

Can you recommend 5 other specialists in the field with whom I should get in contact?

- I Know some people that are developing some projects in that area and I can recommend them. There are both on my Master's program.

Once again, thank you for your time and valuable insights.

Appendix C – Data analysis (MAXQDA 12 first order concepts - totals)



Appendix D – Data structure - First order concepts and Key themes